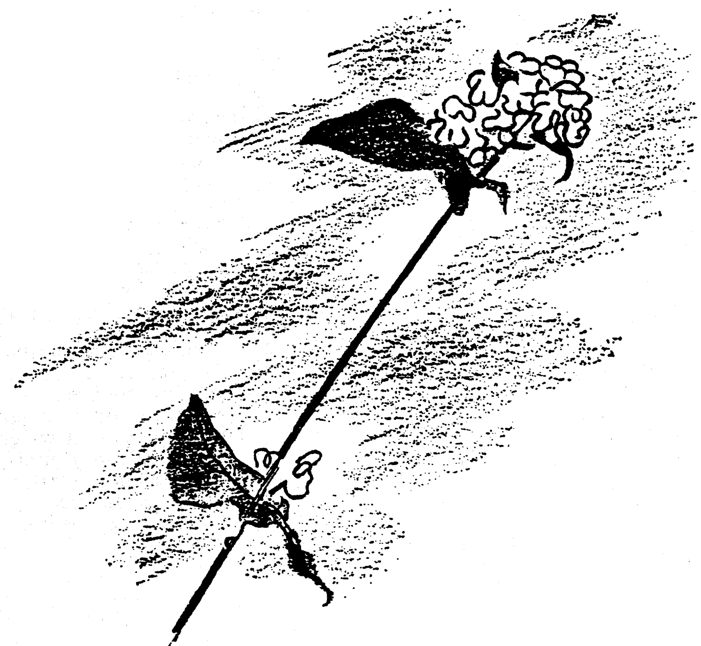
958

Effects of Agronomic Factors on the Rutin Content of Buckwheat



Technical Bulletin No. 1132

U. S. DEPARTMENT OF AGRICULTURE
in cooperation with
the Pennsylvania Agricultural
Experiment Station

The project reported here was carried out cooperatively by the Eastern Utilization Research Branch and the Field Crops Research Branch, Agricultural Research Service, United States Department of Agriculture, and the Agricultural Experiment Station of The Pennsylvania State University. At the time of this research two of the Department authors—Naghski and Couch—were in the former Bureau of Agricultural and Industrial Chemistry; the other two—Taylor and Sando—were in the former Bureau of Plant Industry, Soils, and Agricultural Engineering.

CONTENTS

Effects of Agronomic Factors on the Rutin Content of Buckwheat[1]

By J. NAGHSKI, *chemist, Eastern Utilization Research Branch*, J. F. COUCH,[2] J. W. TAYLOR,[3] and W. J. SANDO, *agronomist, Field Crops Research Branch, Agricultural Research Service, United States Department of Agriculture*, and J. W. WHITE,[4] *professor, Soil Technology*, F. J. HOLBEN, *assistant professor, Soil Technology*, and J. B. WASHKO, *professor of Agronomy, of the Agricultural Experiment Station of The Pennsylvania State University*.[5]

INTRODUCTION

Use of rutin as a medicinal agent has greatly stimulated the production of this compound. Rutin is prescribed for the treatment of vascular disorders characterized by abnormally fragile or permeable capillaries. Correction by rutin of increased capillary fragility results in a decreased incidence of vascular complications such as retinal hemorrhage, apoplexy, and coronary occlusion. The clinical applications of rutin together with its chemistry and pharmocology have been summarized extensively in a recent book by Griffith, Krewson, and Naghski (5)[6]. Demands for this drug have prompted many investigators not only to reevaluate old sources but also to search for new ones.

During the summers of 1944 and 1945 numerous samples of buckwheat of the Japanese variety (*Fagopyrum esculentum*), grown at the Eastern Regional Research Laboratory just outside Philadelphia, were examined for rutin content. The rutin content was considerably greater than that reported by earlier investigators. These studies established the fact that buckwheat could be an important domestic commercial source of this drug, which is a flavonol glycoside (*1*).

Later studies revealed that Tartary buckwheat is from 45 to 80 percent richer in rutin than the Japanese variety, and produces greater yields of rutin per acre (*3*). The Tartary also has a higher proportion of leaves and yields a greater quantity of leaf per acre. This finding is especially important in producing buckwheat leaf meal

---

[1] Submitted for publication April 26, 1955.

[2] Died August 9, 1951.

[3] Retired July 1951.

[4] Retired June 1948.

[5] The authors are indebted to O. E. Street, of the former Bureau of Plant Industry, Soils, and Agricultural Engineering, for the installation and supervision of the experiment at Lancaster, and to W. L. Porter and C. S. Fenske, Eastern Utilization Research Branch, for assistance in sampling and analyzing plant material.

[6] Italic numbers in parentheses refer to Literature Cited, p. 49.

of high rutin content by fractional drying, for the greater portion of the rutin is in the leaves and blossoms; only a small percentage is in the stems (*14*). Unlike the Japanese and Silverhull varieties, the Tartary is indeterminate in growth habit and continues to grow even after seeds have formed; consequently, it maintains its rutin content at a high level for a longer time. This means that the harvest period for this variety is not so limited or so critical as that for the Japanese. Furthermore, since the Tartary is more frost resistant, it can be planted earlier in the spring, and its harvest time can be prolonged in the fall. This condition gives a more extended growing season than is possible for the Japanese. In addition to these cultural advantages, Tartary buckwheat is better suited for dehydrating. It can be dried successfully at higher temperatures and with less critical control, so that drier capacities required are smaller than those needed for Japanese buckwheat (*4*, *18*). Methods for extracting and refining rutin have been published (*9*).

To determine the effects of various agronomic and physiologic factors on the production of rutin by buckwheat, five varieties—Japanese, Silverhull, Tartary, Tetraploid, and Emarginatum—were grown in central and eastern Pennsylvania on Hagerstown, Dekalb, Volusia, and Lansdale silt loams. The results—the effects of age of plants, date of planting, rate of seeding, fertilizer, and manner of harvesting on the production of rutin and dry matter—are reported in this bulletin.

DESCRIPTION OF EXPERIMENTAL PLOTS

In each experiment the soil was plowed and harrowed several days before the seeds were planted, and the seedbed was firmed by use of a cultipacker. The experiments are discussed under the names of the respective soil types used.

Hagerstown Silt Loam at Lancaster, Pa.

The first experiment was conducted in 1946 on Hagerstown silt loam at the Tobacco Experiment Laboratory in Lancaster, Pa. Effects of fertilizing with phosphorus alone, or phosphorus in combination with potassium or nitrogen and potassium, were studied. Phosphorus was applied at the rate of 60 pounds of phosphorus pentoxide (P_2O_5, as superphosphate) per acre, potassium at the rate of 60 pounds of potash (as potassium chloride) per acre, and nitrogen (as ammonium sulfate) at the rate of 20 pounds per acre. Untreated soil was used as a control. All the plots except one contained 9 rows each of Tartary and Japanese buckwheat, 3 rows of Japanese being alternated with 3 rows of Tartary (fig. 1, *A*). The rows were 12 inches apart. One plot treated with nitrogen-phosphorus-potassium contained the Tetraploid variety instead of the Japanese. The Tartary and Tetraploid were planted at the rate of 2½ pecks of seed per acre and the Japanese at the rate of 4 pecks per acre. Plantings were made on May 13, June 13, and August 1. The first samples were taken when the buckwheat was from 5 to 7 inches high.

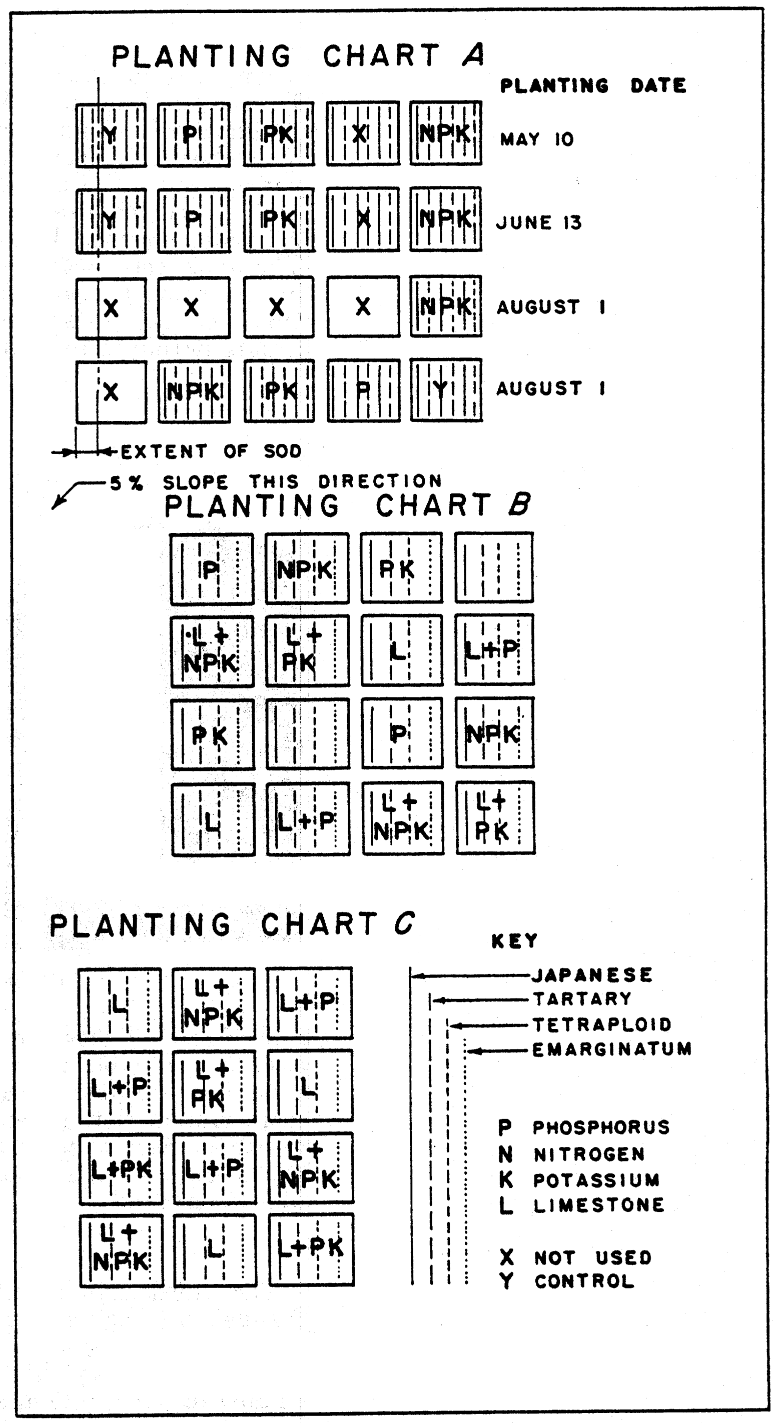


FIGURE 1.—Planting charts of plots in buckwheat experiments on silt loams in Pennsylvania: *A*, On Hagerstown at Lancaster; *B*, on Dekalb near Woodland and on Volusia near Montrose; and *C*, on Hagerstown at State College.

Dekalb Silt Loam

The second experiment in the series was conducted in 1947 on Dekalb silt loam near Woodland, Clearfield County, Pa. The field, which had been uncropped from 1940 to 1945, had been planted in buckwheat in 1946 after being fertilized with 200 pounds of 20-percent superphosphate per acre. To permit three replications of each treatment, this experiment included twelve 20- by 20-foot plots. All plots received limestone at the rate of 1,000 pounds per acre. The plots were treated with the same combinations of fertilizers used in the previous experiment. The control received only limestone. On June 13, 5 rows each of Japanese, Tartary, Tetraploid, and Emarginatum were planted 1 foot apart in each plot (fig. 1, *B*). The rate of seeding was the equivalent of 1 seed to each 2 inches in the row, or 120 viable seeds per row.

FIGURE 2.—Buckwheat 35 days old.

Samples for determination of yields of leaves and stems and their rutin content were taken on July 24 and August 6 and 18. Measurements for relative heights of the plants were made on July 15 and 24 and August 6 and 18. Figure 2 shows the plots when the buckwheat was 35 days old.

Volusia Silt Loam

The third experiment was conducted in 1947 near Montrose, Susquehanna County, Pa. The field had been planted in oats in 1945 and later seeded to mixed red and alsike clover. In the fall of 1946 the clover sod had been plowed under. The arrangement and number of plots, rate of seeding, varieties of buckwheat, and fertilizer treatments were the same as those in the experiment on Dekalb soil (fig. 1, *B*). The plots were seeded on June 24. Samples for the determination of yields of stems and leaves were taken on August 25, and for rutin analysis on August 12 and 25. Measurements for height were made on July 30 and August 11 and 25.

Hagerstown Silt Loam at State College, Pa.

The fourth experiment in the series was made in 1947 on Hagerstown silt loam at The Pennsylvania State University Agricultural Experiment Station, at State College, Pa. The area included plots 5, 6, and 7 of tier 4 from a previous experiment (*15*) designed to study the effect of phosphatic fertilizer and had been uncropped since 1941. The buckwheat experiment included sixteen 16- by 10-foot plots arranged as shown in figure 1, *C*. Rates of application of nitrogen, phosphorus, and potassium were the same as those used in experiments on the Dekalb and Volusia soils.

This experiment differed from the other two conducted in 1947 in that one-half of the plots were not treated with limestone. The plots were seeded to the four varieties of buckwheat—Japanese, Tartary, Tetraploid, and Emarginatum—on July 11. Measurements for height of plants were made on August 15, 22, and 29, and samples for determination of yields of stems and leaves and their rutin content were taken on September 2.

Lansdale Silt Loam

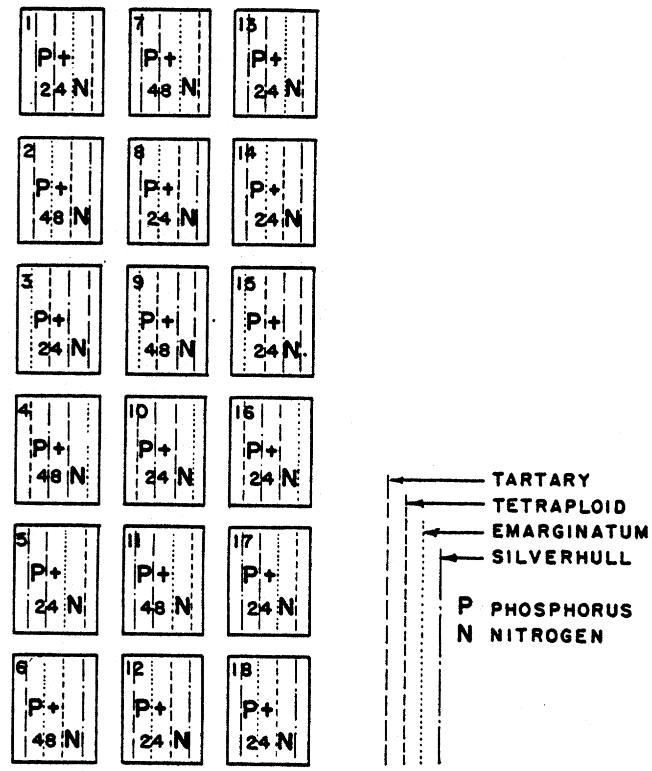
The fifth experiment was made in 1948 near Horsham, Montgomery County, Pa., on Lansdale silt loam of the best-drained phase of this soil type. The field had been uncropped for a number of years, but in 1947 it had been seeded to soybeans without fertilizer treatment. The primary purpose of this experiment was to determine the effect of the rate of seeding on the yield of dry matter and the rutin content. The Tartary, Tetraploid, Emarginatum, and Silverhull varieties were used. Superphosphate was applied uniformly to 31- by 20-foot plots at the rate of 48 pounds of phosphorus pentoxide per acre. No limestone was applied. Figure 3 shows the number and arrangement of plots and the rates of application of nitrogen and seeding. In the rows spaced 14 inches apart an excess of seed was planted, and the rows were later thinned so that the plants were spaced 4 or 6 inches apart in the row. In the rows 7 inches apart, sufficient seed was planted to furnish 240 viable seeds a row, or 1 seed to each inch of row.

The plots were seeded on June 10 and 11. Measurements for height were made on July 8 and 27 and August 10 and 27; samples for a determination of yields of stems and leaves were taken on July 27 and August 10, and samples for a determination of rutin content were taken at weekly intervals from July 12 until August 9.

Composition of Soils

The soil used in the experiment made in 1946 was not analyzed, but in each of the other four experiments a composite soil sample representative of the area was taken before the application of ferti-

PLANTING CHART



PLOT NO	INCHES BETWEEN ROWS	INCHES BETWEEN PLANTS	ROWS PER PLOT EACH VARIETY
1 - 10 - 17	7	1	11
3 - 12 - 15	14	4	6
5 - 8 - 13	14	6	6
2 - 9 - 16	7	1	11
4 - 7 - 18	14	4	6
6 - 11 - 14	14	6	6

FIGURE 3.—Planting chart of plots in buckwheat experiment on Larsdale silt loam near Horsham.

lizers and limestone. Available potassium and phosphorus contents, pH, and limestone requirements were determined. The methods used were as follows: For available phosphorus, Truog's method (*21*); for available potassium, the method of Volk and Truog (*22*); and for limestone requirement, the procedure described by White, Holben, and Richer (*23*). The pH value was determined by electrometric titration with a glass electrode. Table 1 shows the results. The four soils were above average in their available potassium and phosphorus contents. With the exception of the Volusia soil, they were too acid to produce normal yields of most farm crops other than buckwheat.

TABLE 1.—*Analyses and limestone requirements of soils used in buckwheat experiments in 1947 and 1948*

Soil type	Available phosphorus per acre	Available potassium per acre	pH	Limestone requirement per acre
	Pounds	*Pounds*		*Pounds*
Dekalb	66	147	4.3	6,731
Volusia	78	265	6.1	1,791
Hagerstown at State College	49	123	5.5	2,607
Lansdale	48	160	4.9	4,673

Varieties of Buckwheat

Common buckwheat (*Fagopyrum esculentum*) was represented in these experiments by two varieties, Japanese and Silverhull. They are the varieties grown in America for buckwheat flour and various commercial byproducts (*23*).

Tartary buckwheat (*Fagopyrum tataricum*) is known in various localities under such names as "Duckwheat," "Rye buckwheat," "Marino," "Mountain," "Siberian," "Wild Goose," "Hull-less," and "Bloomless." Because the Tartary produces small grain, it is grown to only a slight extent in this country. Owing to its high percentage of hull and a characteristic bitter taste, the grain of this variety is unsuited for human consumption; it is used exclusively for cattle and poultry feed. Until 1946 there was no commercial supply of seed available. Previous experiments at the Pennsylvania Agricultural Experiment Station (*23*) had shown that the Tartary produces on an average 40 percent higher yields of leaves than the Japanese variety, which up to 1945 had been the only variety used for rutin studies. Figure 4 shows a typical field of Tartary buckwheat at harvest time.

Notch-seeded buckwheat (*Fagopyrum emarginatum*) is sometimes known as wing-seeded buckwheat. There is a difference of opinion concerning the nature and classification of this buckwheat. Hunt (*6*) lists it as a separate species, whereas Quisenberry and Taylor (*19*) state that there is no difference between the Emarginatum and the Japanese other than the shape of the seed, and they suggest that the Emarginatum should be considered only as a variety or type of Japanese and not as a different species. However, observations made during this study on growth habit, production of rutin, yields of stems

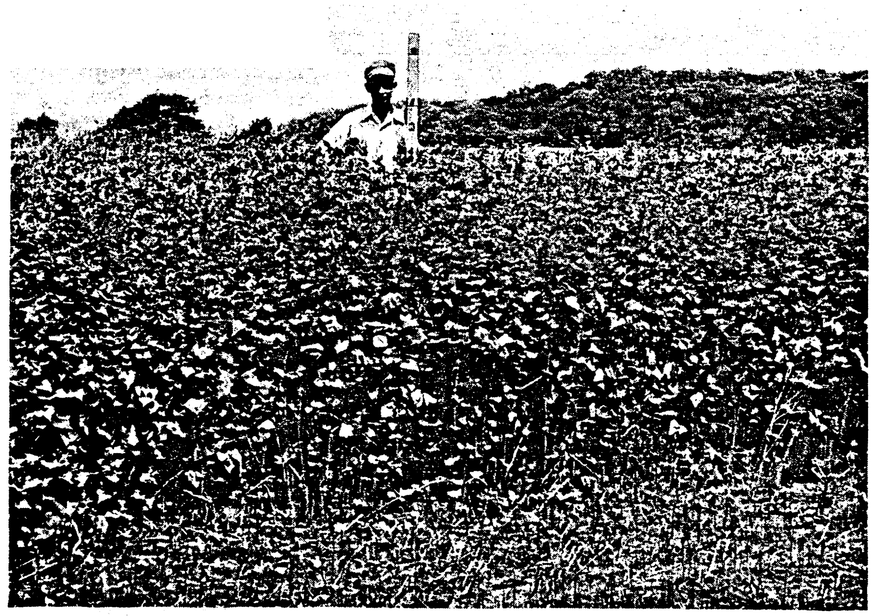


FIGURE 4.—Tartary buckwheat ready for harvesting for production of rutin.

and leaves, response to agronomic factors, and seed production strongly indicate that the Emarginatum should be treated as a definite species.

The Tartary-Tetraploid (*Fagopyrum tetra-tataricum*) was developed from the Tartary by Sando (*20*).

SAMPLING AND ANALYSES OF BUCKWHEAT

Sampling Method

In sampling, plants were selected at random and as representative of the plots as possible; unusually large or small plants were avoided. Samples were cut 1 inch above the ground in order not to disturb the roots of neighboring plants. A 600- to 1,000-gram sample, which contained from 15 to 50 plants, depending on their age and development, was collected from each plot. Wherever the fertilizer treatments were replicated, an equal number of plants were selected from each of the similar plots, combined, and treated as 1 sample. This was necessary because the perishability of the samples made it imperative to analyze them at once, and the number of extractors available limited to 12 the samples that could be analyzed at one time.

Determination of Height

In the 1946 experiment the average height of 30 plants selected at random was taken as the height of the buckwheat on the plot. In the experiments made in 1947 and 1948, height was based on the average of 9 plants, 3 from each of the 3 plots given the same fertilizer treatment.

Determination of Weight

The sample was weighed, and the average weight per green plant was calculated. This was converted to dry weight by means of the moisture factor.

Determination of Moisture

Samples for the determination of moisture were taken immediately after the plants were harvested. A 50- to 100-gram sample of whole plant was weighed to the nearest 0.1 gram in a tared jar; the jar was sealed and taken to the laboratory. Loss in weight after 18 hours at 110° C. was calculated as moisture.

Determination of Rutin

The location of the plots made it necessary to store the samples for 2 to 24 hours before they could be delivered to the laboratory for analysis. To prevent loss of rutin during transportation, the samples were put in ethanol as soon as they were harvested. Duplicate 200-gram samples of whole plant (weighed to the nearest 0.1 gram) were cut in pieces 1 to 2 inches long, placed in a 1-quart fruit jar, and covered with absolute ethanol. The jar then was sealed. Samples preserved in this manner retained their rutin contents unchanged for several days. On arrival at the laboratory the alcoholic solution was decanted and the partly extracted plant material was transferred to a Soxhlet extractor. Extraction was continued with fresh ethanol until the extract was colorless (8 to 12 hours). The combined extracts were concentrated to a small volume (200 ml.) and transferred to a casserole, and the remaining solvent was then evaporated on a steam bath. Water was added to the residue in the casserole (100 ml. for each 0.4 gram of rutin expected), the mixture was boiled for 1 to 2 minutes to dissolve the rutin, and filtered through a rapid filter paper to remove the fatty materials. The filter paper and contents were returned to the casserole, boiled with a small quantity of water, and refiltered. To dissolve all the rutin, this was repeated if necessary. The combined filtrates were stored at room temperature overnight and then in a refrigerator until crystallization was complete (1 or 2 days). The rutin was filtered off in a tared Gooch crucible, washed with cold water, and dried at 110° C. for 4 hours or to a constant weight. The rutin content was calculated on the moisture-free basis (*13*).

Separation of Leaves and Stems

Stems and leaves were weighed separately except in the 1946 experiment. The green plants were stripped of all leaves, and then the stems (chopped finely) and leaves were dried separately to a constant weight in a steam oven at 80° C. They were allowed to remain for several days at room temperature and then weighed. Moisture was determined at 100° C. on composite samples of each variety, and the weights were computed on the moisture-free basis.

Calculation of Results

All data on yields are given on the moisture-free basis. The following formula was used to convert yields from grams per plant to pounds per acre:

Pounds per acre=

$$\text{grams per plant}\left(\frac{\text{square feet per acre}}{\text{square feet per row}}\times\frac{\text{number of plants per row}}{\text{grams per pound}}\right)$$

RESULTS

Buckwheat Grown on Hagerstown Soil at Lancaster, Pa.

Production of Dry Matter

Each of the fertilizer treatments in the experiment on Hagerstown soil at Lancaster increased the yields of dry matter by both Japanese and Tartary buckwheat, as compared with the yield on the untreated soil (table 2). Phosphorus-potassium produced the most outstanding results. Table 3 shows the relative effects of the fertilizer on yields of dry matter. The Japanese and Tartary varieties showed similar responses. The plots treated with nitrogen-phosphorus-potassium produced the greatest increase in yields during the first planting—in May; there was less response to this fertilizer treatment in the two later plantings. This may have been due to a delay in nitrification, which did not make the nitrogen from the plowed-under native plant materials available until later in the season.

Yields of Tartary dry matter were somewhat greater than those of the Japanese. If yields of the Japanese are taken as 100, the Tartary yields had the following values: Untreated plots, 118; phosphorus treated, 118; phosphorus-potassium treated, 113; and nitrogen-phosphorus-potassium treated, 117.

Table 2 also shows the increase of dry matter with age. Plants grown on the nitrogen-phosphorus-potassium treated plots were more succulent than the others, as indicated by their lower content of dry matter. The Japanese matured more rapidly than the Tartary, as shown by its higher dry-matter content at the same age.

Production of Rutin

Data on the rutin contents of the two varieties and the yields of rutin per acre are included in table 2. Except for extremely young plants, the younger plants had the highest percentage of rutin, owing to the greater proportion of leaves to stems. The maximum yields, however, were produced by the more mature plants. Both Japanese and Tartary buckwheat produced higher yields of rutin on the fertilized plots. In the first planting, a definite response to nitrogen-phosphorus-potassium was shown by the Japanese and to phosphorus-potassium by the Tartary. There were no significant differences, however, in the average results of the three fertilizer treatments. This fact is emphasized by the data in table 3, which show the relative values of the fertilizer treatments.

TABLE 2.—*Effects of fertilizers*[1] *on the production of dry matter and rutin and height of two varieties of buckwheat grown on Hagerstown soil at Lancaster*

Age of plants (days after emergence)	Dry matter content								Yields of dry matter per acre								Rutin content			
	Japanese				Tartary				Japanese				Tartary				Japanese			
	U	P	PK	NPK	U	P	PK	NPK	U	P	PK	NPK	U	P	PK	NPK	U	P	PK	NPK
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Percent*	*Percent*	*Percent*	*Percent*
Planted May 13, 1946																				
15	13. 0	10. 8	9. 8	9. 8	13. 2	12. 4	10. 6	9. 9	500	590	590	650	240	470	520	540	3. 54	4. 36	4. 43	3. 56
22	12. 2	13. 6	12. 6	12. 6	13. 8	13. 8	12. 6	12. 0	750	990	1, 250	1, 530	650	950	910	1, 140	4. 98	4. 05	3. 94	4. 95
29	15. 2	16. 6	15. 4	13. 0	12. 8	13. 4	11. 6	11. 2	1, 250	1, 940	2, 260	2, 490	1, 340	1, 790	1, 700	2, 260	3. 99	3. 93	3. 57	3. 56
36	15. 8	17. 0	17. 8	15. 7	12. 8	14. 8	16. 2	14. 6	1, 920	2, 680	2, 880	2, 960	1, 590	2, 150	2, 890	3, 510	3. 24	3. 67	3. 00	3. 05
43	17. 0	17. 6	17. 8	16. 3	14. 2	15. 2	15. 2	14. 8	2, 220	2, 790	3, 410	3, 330	3, 280	2, 990	4, 390	4, 890	2. 97	2. 80	2. 69	2. 26
Planted June 13, 1946																				
22	11. 2	11. 4	13. 0	10. 0	11. 8	12. 0	10. 6	9. 2	1, 690	1, 630	2, 260	2, 030	1, 310	1, 660	1, 700	2, 130	3. 65	3. 75	2. 74	3. 08
30	14. 5	14. 1	14. 2	12. 5	12. 8	13. 8	11. 6	11. 9	2, 540	3, 070	3, 260	3, 300	2, 520	2, 970	2, 840	3, 840	3. 03	3. 04	2. 81	2. 97
43	20. 7	16. 8	18. 6	17. 5	16. 7	17. 4	16. 6	14. 4	4, 460	4, 510	4, 570	4, 450	4, 610	5, 300	5, 580	4, 760	2. 10	2. 90	2. 25	2. 10
Planted August 1, 1946																				
13	8. 6	8. 2	8. 4	8. 5	----	----	----	----	500	590	580	610	----	----	----	----	2. 51	2. 46	2. 79	2. 82
20	10. 4	9. 4	10. 2	11. 2	7. 9	8. 9	8. 7	8. 7	1, 340	1, 550	1, 600	1, 540	820	1, 510	1, 510	1, 140	2. 52	2. 36	2. 68	2. 98
26	12. 9	11. 9	11. 1	12. 6	8. 8	9. 9	10. 3	10. 6	2, 110	2, 960	1, 620	2, 740	1, 960	2, 590	2, 460	2, 860	2. 60	2. 28	3. 05	2. 54
34	14. 4	16. 6	15. 2	15. 4	10. 8	13. 3	11. 4	14. 3	2, 980	4, 140	4, 260	2, 690	4, 030	6, 980	4, 570	4, 520	1. 84	1. 57	2. 22	2. 15
41	18. 1	19. 4	19. 3	19. 3	15. 4	14. 8	18. 7	17. 5	4, 000	5, 480	6, 000	5, 460	8, 040	8, 860	9, 350	7, 260	1. 23	1. 17	1. 12	1. 57
48	----	----	----	----	18. 0	15. 8	18. 9	15. 2	----	----	----	----	8, 980	14, 280	11, 290	11, 460	----	----	----	----

[1] U = untreated; P = phosphorus; K = potassium; N = nitrogen.

TABLE 2.—*Effects of fertilizers*[1] *on the production of dry matter and rutin and height of two varieties of buckwheat grown on Hagerstown soil at Lancaster*—Continued

Planted May 13, 1946

Age of plants (days after emergence)	Rutin content—Con.				Yields of rutin per acre								Height of plants							
	Tartary				Japanese				Tartary				Japanese				Tartary			
	U	P	PK	NPK	U	P	PK	NPK	U	P	PK	NPK	U	P	PK	NPK	U	P	PK	NPK
	Percent	*Percent*	*Percent*	*Percent*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
15	4. 39	5. 02	5. 75	4. 20	18	26	26	23	11	23	30	23	7	10	10	11	4	7	7	10
22	5. 80	5. 62	5. 86	4. 85	37	40	49	76	38	54	53	55	10	16	11	19	6	11	11	15
29	5. 46	5. 37	5. 91	4. 57	50	76	81	89	73	96	100	103	19	24	24	27	13	18	18	25
36	5. 02	4. 50	3. 91	3. 84	62	98	86	90	80	97	113	135	24	26	28	30	21	26	28	34
43	4. 86	4. 82	4. 19	3. 61	66	78	92	75	159	144	184	177	25	26	29	34	30	35	38	43

Planted June 13, 1946

22	3. 92	4. 36	3. 68	3. 46	62	61	62	63	51	72	63	74	22	25	26	29	17	19	20	24
30	3. 90	4. 76	4. 10	3. 30	77	93	92	98	98	141	116	127	33	33	37	38	26	26	30	32
43	3. 75	3. 27	3. 32	3. 72	94	131	103	93	173	173	185	177	----	----	----	----	----	----	----	----

Planted August 1, 1946

13	----	----	----	----	13	15	16	17	----	----	----	----	10	12	11	12	----	----	----	----
20	3. 23	2. 60	2. 98	3. 94	34	37	43	46	27	39	45	45	20	22	21	20	16	18	17	16
26	2. 67	3. 01	3. 19	3. 07	55	67	49	70	52	78	79	88	30	32	30	29	28	30	28	27
34	2. 97	2. 47	3. 44	2. 86	55	65	95	58	120	150	157	129	33	35	32	31	41	41	39	38
41	2. 18	3. 08	2. 35	2. 76	49	64	67	86	175	273	220	200	32	36	37	30	43	42	40	34
48	2. 16	2. 72	2. 00	2. 14	----	----	----	----	194	388	226	245	----	----	----	----	43	51	43	39

[1] U=untreated; P=phosphorus; K=potassium; N=nitrogen.

TABLE 3.—*Relative effects of fertilizers* [1] *on yields of dry matter and rutin by two varieties of buckwheat grown on Hagerstown soil at Lancaster.* (*Untreated plot=100*)

Age of plants (days after emergence)	Dry matter						Rutin					
	Japanese			Tartary			Japanese			Tartary		
	P	PK	NPK	P	PK	NPK	P	PK	NPK	P	PK	NPK
						Planted May 13, 1946						
15	118	118	130	196	217	225	144	144	128	209	273	209
22	132	167	204	146	140	175	108	132	205	142	139	145
29	155	181	199	134	127	169	152	162	178	132	137	141
36	140	150	154	135	182	221	158	139	145	121	141	169
43	126	154	150	91	134	149	118	139	114	91	116	113
						Planted June 13, 1946						
22	96	134	120	127	130	163	98	100	102	141	124	145
30	121	128	130	118	113	152	121	119	127	144	118	130
43	101	102	100	115	121	103	139	110	99	100	107	102
						Planted August 1, 1946						
13	118	116	123	----	----	-----	115	123	131	----	----	-----
20	116	119	115	184	184	139	109	126	135	144	167	167
26	140	77	130	132	126	146	122	89	127	150	152	169
34	139	143	90	173	113	112	118	173	105	125	131	108
41	137	150	137	110	116	90	131	137	176	156	126	114
48	----	----	-----	159	126	128	----	----	-----	200	116	126

[1] P=phosphorus; K=potassium; N=nitrogen.

The outstanding finding in this experiment is the marked superiority of the Tartary over the Japanese in yield of rutin. If the yields by the Japanese variety are taken as 100, the yields by the Tartary had the following values: Untreated plots, 145; phosphorus treated, 160; phosphorus-potassium treated, 159; and nitrogen-phosphorus-potassium treated, 153. The average results of the four treatments show that the Tartary buckwheat produced 54 percent more rutin than the Japanese variety.

Tetraploid Variety Compared With the Tartary

A comparison of the Tetraploid with the Tartary variety, from which it originated, was made on a plot treated with nitrogen-phosphorus-potassium. Table 4 gives the results. Yields of dry matter produced by the two varieties were similar, with the exception of the yields at the end of 48 days, at which time the yield by the Tartary was about 57 percent more than that by the Tetraploid. On the

TABLE 4.—*Yields of dry matter and rutin produced by two varieties of buckwheat grown on Hagerstown soil at Lancaster on a single plot treated with nitrogen-phosphorus-potassium*

Age of plants[1] (days after emergence)	Dry matter content		Yields of dry matter per acre		Rutin content		Yields of rutin per acre	
	Tetraploid	Tartary	Tetraploid	Tartary	Tetraploid	Tartary	Tetraploid	Tartary
	Percent	*Percent*	*Pounds*	*Pounds*	*Percent*	*Percent*	*Pounds*	*Pounds*
13	9. 9	8. 6	470	430	2. 63	2. 82	12	12
20	9. 6	9. 5	1, 490	1, 310	2. 63	3. 52	39	46
28	8. 0	9. 4	2, 990	2, 990	3. 04	2. 76	91	83
32	10. 8	12. 1	4, 290	5, 230	2. 68	2. 92	115	153
41	13. 8	16. 5	9, 330	9, 520	2. 68	2. 64	250	251
48	14. 8	15. 0	8, 580	13, 440	1. 64	1. 86	141	250

[1] Planted August 1, 1946.

average, the Tartary produced 21 percent more rutin than the Tetraploid.

Height of Plants

Table 2 also shows the height of the buckwheat at different ages. The average results of all the treatments show that the plants increased in height on the fertilized plots. During the three planting periods, the Japanese attained average heights of 21, 30, and 26 inches, respectively, as compared with 20, 25, and 34 inches attained by the Tartary. In general, there was little difference in the heights attained during the three plantings.

Buckwheat Grown on Dekalb Soil

Production of Dry Matter

Table 5 shows the yields of stems and leaves by buckwheat grown on Dekalb soil. There was a progressive decrease in the percentage of leaf with the age of the buckwheat. This was due in part to the weight of the seed, which was included in the weight of the stems. The weight of the leaves did not increase appreciably after the plants were 48 days old.

The fertilizers had only limited value over limestone used alone, with the exception of the limestone-nitrogen-phosphorus-potassium treatment, which had a relatively high value in the production of total dry matter. The data in table 6 show more clearly the relative values of the four treatments. The limestone-nitrogen-phosphorus-potassium and limestone-phosphorus produced an average of 37 and 7 percent higher yields, respectively, than limestone used alone; limestone-phosphorus-potassium gave a slightly lower yield. The Dekalb soil contained 66 pounds per acre of available phosphorus and 147 pounds of potassium (table 1), which apparently were sufficient for the immediate needs of the buckwheat because of its relatively strong feeding power for residual plant nutrients. The total yields of dry matter of the four varieties of buckwheat were similar. There was a significant difference in leaf yields, however, which is of major importance in the production of rutin. On the basis of the average of the four fertilizer treatments, with the Japanese variety taken as 100, the relative leaf yields had the following values: Tartary, 108; Tetraploid, 180; and Emarginatum, 149.

Production of Rutin

Table 5 shows the rutin content of the buckwheat grown on Dekalb soil. The Japanese produced higher yields of rutin with each of the fertilizer treatments than with limestone alone. Limestone-phosphorus-potassium, however, produced only a slight gain over limestone alone and lower yields than limestone-phosphorus. The residual available potassium in this soil was apparently sufficient to meet the demands for potassium. Limestone-nitrogen-phosphorus-potassium produced relatively high yields of rutin, as compared with limestone-phosphorus-potassium. Table 6 shows that the limestone-phosphorus produced an average increase in yields of 16 percent over limestone alone, as compared with 2 percent for limestone-phosphorus-potassium and 47 percent for limestone-nitrogen-phosphorus-potassium.

The effects of the fertilizers on the yields of rutin by the Tartary variety were somewhat different from those by the Japanese. Table 6 shows that limestone-phosphorus-potassium produced an average increase in rutin of 16 percent over the yield when limestone was used alone, and limestone-nitrogen-phosphorus-potassium produced a 75-percent increase. Nitrogen was of major importance in the production of rutin and buckwheat dry matter.

Table 5 includes the few data obtained on the Tetraploid and Emarginatum varieties. Since lack of facilities limited the number of analyses, the effects of only the limestone-nitrogen-phosphorus-potassium treatment were determined for the Tetraploid and Emarginatum throughout the period of growth. Table 7 shows the relative yield of rutin by each of the four buckwheat varieties treated with limestone-nitrogen-phosphorus-potassium. The average results of the three sampling periods show that the Tartary, Tetraploid, and Emarginatum have much higher value for rutin production than the Japanese.

Height of Plants

Table 8 shows the heights attained by the buckwheat plants in this experiment at four periods of growth. In the first 48 days, measured from the time the plants emerged from the ground, the Japanese variety attained a height greater than that of the other varieties, but after that period there was little further growth. At the end of the 60-day period the Tartary had attained the greatest height, followed in order by the Emarginatum and Tetraploid. The greater height of the Tartary plants at maturity is due to a vinelike terminal growth. With the exception of limestone-nitrogen-phosphorus-potassium, the fertilizers and limestone had no significant effect on the height of the plants.

348103°—55——3

TABLE 5.—*Effects of fertilizers on the production of leaves, stems, dry matter, and rutin by varieties of buckwheat grown on Dekalb soil. Plants emerged on June 19, 1947.*

Fertilizer	Leaves per acre (dry weight)				Portion of total dry matter				Stems per acre (dry weight)			
	Japanese	Tartary	Tetraploid	Emarginatum	Japanese	Tartary	Tetraploid	Emarginatum	Japanese	Tartary	Tetraploid	Emarginatum
Plants 35 days old												
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Percent*	*Percent*	*Percent*	*Percent*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Limestone	420	400	640	610	51.0	65.3	69.9	62.9	400	210	280	360
Limestone-phosphorus	510	530	750	560	53.1	60.1	70.2	53.8	450	350	320	480
Limestone-phosphorus-potassium	460	360	530	660	51.4	64.9	69.7	61.2	440	190	230	420
Limestone-nitrogen-phosphorus-potassium	740	660	650	580	49.5	51.9	64.1	60.3	750	610	370	380
Plants 48 days old												
Limestone	670	600	1,410	1,230	20.2	35.8	50.0	36.1	2,640	1,070	1,410	2,170
Limestone-phosphorus	540	620	1,380	1,150	19.4	33.6	48.4	33.6	2,260	1,220	1,470	2,270
Limestone-phosphorus-potassium	520	640	1,380	1,150	19.4	33.6	48.4	33.6	2,160	1,260	1,470	2,270
Limestone-nitrogen-phosphorus-potassium	990	1,190	1,790	1,350	24.1	38.9	47.7	35.1	3,110	1,880	1,960	2,490
Plants 60 days old												
Limestone	740	620	1,360	1,380	18.7	19.3	30.6	24.1	3,240	2,580	3,090	4,330
Limestone-phosphorus	760	980	1,500	1,050	14.2	21.3	28.3	22.0	4,600	3,600	3,790	3,740
Limestone-phosphorus-potassium	870	1,050	1,280	1,010	19.1	22.0	30.8	21.7	3,700	3,710	2,890	3,620
Limestone-nitrogen-phosphorus-potassium	940	1,140	2,050	1,430	18.1	19.5	31.5	24.0	4,230	4,710	4,450	4,520

Fertilizer	Dry matter content				Rutin content				Yields of rutin per acre			
	Japanese	Tartary	Tetraploid	Emarginatum	Japanese	Tartary	Tetraploid	Emarginatum	Japanese	Tartary	Tetraploid	Emarginatum
Plants 35 days old												
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Limestone	12.8	13.2	------	------	3.89	5.34	------	------	32	33	------	------
Limestone-phosphorus	13.3	12.9	------	------	4.05	5.25	------	------	39	46	------	------
Limestone-phosphorus-potassium	13.0	9.9	------	------	3.62	5.65	------	------	33	31	------	------
Limestone-nitrogen-phosphorus-potassium	10.9	10.7	11.3	10.8	3.42	4.57	4.02	3.91	51	58	41	38
Plants 48 days old												
Limestone	21.1	15.8	------	------	2.68	5.30	------	------	89	89	------	------
Limestone-phosphorus	18.8	19.1	------	------	3.50	4.40	------	------	98	81	------	------
Limestone-phosphorus-potassium	18.0	13.5	------	------	3.37	5.56	------	------	90	106	------	------
Limestone-nitrogen-phosphorus-potassium	17.9	16.0	15.0	14.0	2.94	4.85	4.59	3.66	121	149	172	141
Plants 60 days old												
Limestone	------	21.9	20.6	20.3	------	3.59	3.85	2.84	------	115	171	162
Limestone-phosphorus	------	26.4	21.5	18.0	------	3.17	3.27	3.34	------	145	173	160
Limestone-phosphorus-potassium	------	21.1	------	------	------	3.25	------	------	------	155	------	------
Limestone-nitrogen-phosphorus-potassium	23.5	17.8	25.6	18.0	2.34	3.57	2.66	3.22	121	209	173	192

TABLE 6.—*Relative effects of fertilizers and age of plants on yields of leaves, stems, and rutin by varieties of buckwheat grown on Dekalb soil. (Limestone=100)*

Fertilizer	Leaves [1]	Stems [1]	Rutin	
			Japanese	Tartary
Plants 35 days old				
Limestone-phosphorus	114	128	122	139
Limestone-phosphorus-potassium	97	102	103	94
Limestone-nitrogen-phosphorus-potassium	127	169	159	176
Plants 48 days old				
Limestone-phosphorus	94	99	110	91
Limestone-phosphorus-potassium	94	98	101	119
Limestone-nitrogen-phosphorus-potassium	136	129	135	167
Plants 60 days old				
Limestone-phosphorus	105	119	--------	126
Limestone-phosphorus-potassium	103	105	--------	135
Limestone-nitrogen-phosphorus-potassium	136	135	--------	182

[1] Average of the Japanese, Tartary, Tetraploid, and Emarginatum varieties.

TABLE 7.—*Relative yields of rutin from varieties of buckwheat grown on Dekalb soil treated with limestone-nitrogen-potassium-phosphorus. (Japanese=100)*

Age of plants (days)	Rutin		
	Tartary	Tetraploid	Emarginatum
35	114	80	75
48	123	142	117
60	173	143	159
Average	137	122	117

TABLE 8.—*Effects of fertilizers on the height (average) of varieties of buckwheat grown on Dekalb soil*

Fertilizer	Japanese	Tartary	Tetraploid	Emarginatum
Plants 26 days old				
	Inches	*Inches*	*Inches*	*Inches*
Limestone	10	7	6	8
Limestone-phosphorus	12	7	6	8
Limestone-phosphorus-potassium	11	7	7	9
Limestone-phosphorus-nitrogen-potassium	17	12	8	11
Plants 35 days old				
Limestone	22	15	11	15
Limestone-phosphorus	23	17	12	16
Limestone-phosphorus-potassium	22	14	12	14
Limestone-phosphorus-nitrogen-potassium	29	22	17	20
Plants 48 days old				
Limestone	36	36	27	34
Limestone-phosphorus	38	36	29	36
Limestone-phosphorus-potassium	35	32	27	33
Limestone-phosphorus-nitrogen-potassium	42	42	33	37
Plants 60 days old				
Limestone	36	50	41	47
Limestone-phosphorus	38	51	43	51
Limestone-phosphorus-potassium	39	51	41	48
Limestone-phosphorus-nitrogen-potassium	45	55	46	52

Figure 5 shows the average daily growth rate of the plants at four periods during the experiment. The Japanese variety grew most rapidly between the 26th and 35th days following emergence; the other three varieties grew most rapidly between the 35th and 48th days.

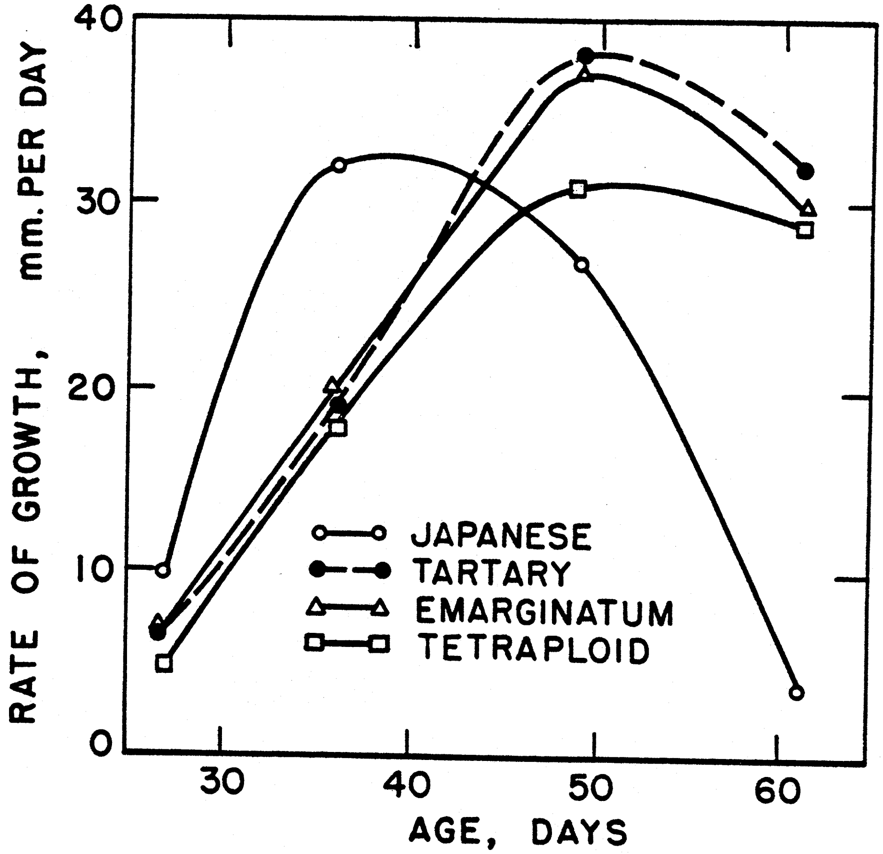


FIGURE 5.—Average daily growth rate of buckwheat grown on Dekalb soil.

Buckwheat Grown on Volusia Soil

Production of Dry Matter

Table 9 shows the effects of fertilizers on the production of leaves, stems, and dry matter by buckwheat grown on Volusia soil. With the exception of leaf yields by Japanese and Tartary on the plot treated with limestone-phosphorus-potassium, each of the fertilizer treatments produced yields of dry matter greater than those produced by limestone alone. The Volusia soil contained 78 pounds of available phosphorus per acre and 265 pounds of available potassium (table 1), which accounts for the relatively small increases produced by applied phosphorus and potassium. The relatively low result for limestone-nitrogen-phosphorus-potassium, as compared with that for limestone-phosphorus-potassium, was due to the fact that a fertilized clover sod had been plowed under in the fall of 1946. A Volusia soil relatively low in available phosphorus and potassium gave marked response to the application of these two essential plant nutrients (*23*). Table 10 shows more clearly the relative values of the plant nutrients added.

TABLE 9.—*Effects of fertilizers on yields of leaves and stems by four varieties of buckwheat grown on Volusia soil. Plants were 56 days old.*

Fertilizer	Leaves per acre				Stems per acre				Total dry matter per acre			
	Japanese	Tartary	Tetraploid	Emarginatum	Japanese	Tartary	Tetraploid	Emarginatum	Japanese	Tartary	Tetraploid	Emarginatum
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Limestone	830	1, 290	1, 380	1, 200	4, 890	4, 350	2, 570	3, 270	5, 720	5, 640	3, 950	4, 470
Limestone-phosphorus	1, 060	1, 500	2, 030	1, 550	5, 700	4, 800	3, 790	4, 250	6, 760	6, 300	5, 820	5, 800
Limestone-phosphorus-potassium	720	1, 250	1, 680	1, 230	4, 160	4, 960	3, 640	3, 310	4, 880	6, 210	5, 320	4, 540
Limestone-nitrogen-phosphorus-potassium	980	1, 370	1, 640	1, 340	5, 550	4, 600	3, 470	4, 050	6, 530	5, 980	5, 120	5, 390

TABLE 10.—*Relative effects of fertilizers on the production of leaves, stems, and rutin by varieties of buckwheat grown on Volusia soil. (Limestone=100)*

Fertilizer	Leaves [1]	Stems [1]	Rutin [2]	
			Japanese	Tartary
Limestone-phosphorus	131	123	118	142
Limestone-phosphorus-potassium	104	107	110	120
Limestone-nitrogen-phosphorus-potassium	113	117	103	122

[1] Average of four varieties; plants were 56 days old.
[2] Plants were 43 days old.

Table 11 shows the value of the Tartary, Tetraploid, and Emarginatum relative to the Japanese for production of leaves and stems. These values are based on the average results of the four fertilizer treatments. The Japanese gave the poorest yield of leaves.

Production of Rutin

Table 12 gives data on the rutin content of buckwheat grown on Volusia soil. When the buckwheat was 43 days old, the limestone-phosphorus had produced the greatest effect on the yield of rutin by both the Japanese and Tartary. Later, the limestone-phosphorus-potassium treatment showed a slight advantage. The relatively slight response to limestone-nitrogen-phosphorus-potassium was due to the nitrogen supplied by the clover sod plowed under the preceding fall. Table 10 gives the relative values of the fertilizer treatments in the production of rutin. The Japanese variety produced less rutin than the Tartary, Tetraploid, and Emarginatum (results of the limestone-nitrogen-phosphorus-potassium treatment in table 11). The Tartary produced about 49 percent more rutin than the Japanese (average results of the two sampling periods). The Tetraploid and Emarginatum varieties produced 60 and 21 percent more rutin, respectively, than the Japanese.

Height of Plants

The effects of fertilizers on the height of buckwheat (table 13) were similar to their effects on the yields of dry matter. The data in table 13 also show the differences in the rate of development of the four varieties and emphasize the more rapid growth of the Japanese during the first 42 days.

Table 14 shows the average daily rate of growth of the four varieties.

TABLE 11.—*Relative production of leaves, stems, and rutin by four varieties of buckwheat grown on Volusia soil.* (*Japanese=100*)

Age of plants (days)	Leaves [1]			Stems [1]			Rutin [2]		
	Tartary	Tetraploid	Emarginatum	Tartary	Tetraploid	Emarginatum	Tartary	Tetraploid	Emarginatum
43							125	150	87
56	151	187	148	92	66	73	173	169	155

[1] Average results of the four fertilizer treatments.
[2] Based on results with limestone-nitrogen-phosphorus-potassium.

TABLE 12.—*Effects of fertilizers on the production of dry matter and rutin by four varieties of buckwheat grown on Volusia soil*

Fertilizer	Dry matter content				Rutin content				Yields of rutin per acre			
	Japanese	Tartary	Tetraploid	Emarginatum	Japanese	Tartary	Tetraploid	Emarginatum	Japanese	Tartary	Tetraploid	Emarginatum
Plants 43 days old												
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Limestone	16.4	12.3	------	------	3.22	5.48	------	------	118	124	------	------
Limestone-phosphorus	15.1	13.1	------	------	3.42	4.64	------	------	139	176	------	------
Limestone-phosphorus-potassium	16.2	12.7	------	------	3.19	5.15	------	------	130	149	------	------
Limestone-nitrogen-phosphorus-potassium	15.1	12.7	10.1	11.5	3.36	4.62	5.94	3.76	121	151	181	105
Plants 56 days old												
Limestone	------	19.2	17.5	17.4	------	3.42	4.23	3.24	------	193	167	145
Limestone-phosphorus	------	21.1	15.3	16.0	------	3.16	4.38	3.12	------	199	255	181
Limestone-phosphorus-potassium	------	20.0	------	------	------	3.56	------	------	------	221	------	------
Limestone-nitrogen-phosphorus-potassium	20.5	17.6	16.8	14.3	1.86	3.50	3.98	3.47	121	209	204	187

TABLE 13.—*Effects of fertilizers on the height (average) of four varieties of buckwheat grown on Volusia soil*

Plants 30 days old

Fertilizer	Japanese	Tartary	Tetraploid	Emarginatum
	Inches	*Inches*	*Inches*	*Inches*
Limestone	17	7	7	10
Limestone-phosphorus	19	9	9	12
Limestone-phosphorus-potassium	21	10	8	13
Limestone-nitrogen-phosphorus-potassium	22	13	9	15

Plants 42 days old

Fertilizer	Japanese	Tartary	Tetraploid	Emarginatum
Limestone	33	27	19	26
Phosphorus	35	29	21	28
Limestone-phosphorus-potassium	32	32	24	29
Limestone-nitrogen-phosphorus-potassium	36	34	24	30

Plants 56 days old

Fertilizer	Japanese	Tartary	Tetraploid	Emarginatum
Limestone	38	49	39	47
Phosphorus	41	50	46	48
Limestone-phosphorus-potassium	38	53	45	46
Limestone-nitrogen-phosphorus-potassium	42	54	46	48

TABLE 14.—*Effects of fertilizers* [1] *on the average daily rate of growth of four varieties of buckwheat grown on Volusia soil*

First 30 days

Buckwheat variety	Daily rate of growth on soil treated with—			
	L	LP	LPK	LNPK
	Milli-meters	*Milli-meters*	*Milli-meters*	*Milli-meters*
Japanese	12	13	15	15
Tartary	5	6	7	9
Tetraploid	5	6	6	6
Emarginatum	7	8	9	10
From 31 to 42 days				
Japanese	33	33	23	29
Tartary	42	42	46	44
Tetraploid	25	25	33	31
Emarginatum	33	33	33	31
From 43 to 56 days				
Japanese	9	11	11	11
Tartary	39	38	38	36
Tetraploid	36	45	38	39
Emarginatum	38	36	30	32

[1] L=limestone; P=phosphorus; K=potassium; N=nitrogen.

Buckwheat Grown on Hagerstown Soil at State College, Pa.

Production of Dry Matter

In the experiment on Hagerstown soil at State College in 1947, samples were taken only once—on September 2—47 days from the date of emergence. On this soil, well supplied with residual phosphorus and potassium, these fertilizers did not exert a pronounced effect on the yield of total dry matter (table 15). They appeared to decrease somewhat the yield of leaves. Applied nitrogen, however, seemed to increase the production of leaves and stems by all varieties except the Emarginatum. The addition of limestone had a depressing effect on the utilization of phosphorus and potassium by the Tetraploid and Emarginatum and of potassium by the Tartary but not by the other varieties. This can be seen more clearly from the data on the relative effects of fertilizers on the yields of dry matter (table 16).

Table 15.—*Effects of fertilizers on the production of leaves, stems, dry matter, and rutin by four varieties of buckwheat grown on Hagerstown soil at State College. Plants were 47 days old.*

Fertilizer	Leaves per acre				Stems per acre				Total dry matter per acre			
	Japanese	Tartary	Tetraploid	Emarginatum	Japanese	Tartary	Tetraploid	Emarginatum	Japanese	Tartary	Tetraploid	Emarginatum
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Untreated	720	1, 010	1, 090	1, 540	3, 030	1, 470	1, 890	3, 070	3, 750	2, 480	2, 980	4, 610
Limestone	460	680	1, 030	1, 240	2, 440	2, 390	1, 280	3, 910	2, 900	3, 070	2, 310	5, 150
Phosphorus	660	940	1, 060	1, 730	2, 800	2, 660	1, 580	4, 680	3, 460	3, 600	2, 640	6, 410
Limestone-phosphorus	620	1, 020	810	1, 280	2, 970	2, 620	1, 350	3, 260	3, 590	3, 640	2, 160	4, 540
Phosphorus-potassium	550	790	1, 140	1, 030	2, 870	2, 060	1, 750	3, 330	3, 420	2, 850	2, 890	4, 360
Limestone-phosphorus-potassium	760	760	1, 040	780	3, 410	1, 960	1, 320	2, 560	4, 170	2, 720	2, 360	3, 340
Nitrogen-phosphorus-potassium	990	1, 370	1, 570	1, 700	3, 500	3, 140	2, 120	2, 770	4, 490	4, 510	3, 690	4, 470
Limestone-nitrogen-phosphorus-potassium	1, 380	1, 150	1, 280	1, 910	4, 530	3, 380	2, 930	3, 150	5, 910	4, 530	4, 210	5, 060

Fertilizer	Dry matter content				Rutin content				Yield of rutin per acre			
	Japanese	Tartary	Tetraploid	Emarginatum	Japanese	Tartary	Tetraploid	Emarginatum	Japanese	Tartary	Tetraploid	Emarginatum
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Untreated	----	----	----	----	----	----	----	----	----	----	----	----
Limestone	24. 3	20. 1	----	----	1. 24	3. 56	----	----	36	109	----	----
Phosphorus	----	20. 5	----	----	----	3. 64	----	----	----	131.	----	----
Limestone-phosphorus	29. 0	18. 2	----	----	1. 41	3. 97	----	----	51	145	----	----
Phosphorus-potassium	----	----	----	----	----	----	----	----	----	----	----	----
Limestone-phosphorus-potassium	22. 0	16. 9	----	----	1. 51	4. 31	----	----	63	117	----	----
Nitrogen-phosphorus-potassium	23. 5	19. 1	16. 3	13. 7	1. 39	3. 42	4. 34	3. 39	62	154	160	152
Limestone-nitrogen-phosphorus-potassium	24. 6	17. 5	16. 4	15. 0	1. 24	3. 57	3. 87	3. 30	73	162	163	167

TABLE 16.—*Relative effects of fertilizers on yields of dry matter and rutin by four varieties of buckwheat grown on Hagerstown soil at State College. (Limestone=100)*[1] *Plants were 47 days old.*

Fertilizer	Dry matter				Rutin	
	Japanese	Tartary	Tetraploid	Emarginatum	Japanese	Tartary
Untreated	129	81	129	90	-------	-------
Phosphorus	119	117	114	124	-------	120
Limestone-phosphorus	124	119	94	88	142	133
Phosphorus-potassium	118	93	125	85	-------	-------
Limestone-phosphorus-potassium	144	89	102	65	175	107
Nitrogen-phosphorus-potassium	155	147	160	87	172	141
Limestone - nitrogen - phosphorus-potassium	204	148	182	98	203	149

[1] The limestone treatment was used as a base, because samples were not taken from the untreated plots for rutin analyses.

The outstanding results of this experiment are the comparative yields of leaves by the different varieties. The superiority of the Tartary, Tetraploid, and Emarginatum varieties over the Japanese is emphasized by the data in table 17. By averaging the yields of the eight plots it was found that the Tartary leaf yields were 26 percent higher than the Japanese; the Tetraploid and Emarginatum produced 47 and 83 percent more, respectively, than the Japanese.

TABLE 17.—*Relative yields of leaves and rutin by four varieties of buckwheat grown on Hagerstown soil at State College. (Japanese=100) Plants were 47 days old.*

Fertilizer	Leaves (dry weight)			Rutin		
	Tartary	Tetraploid	Emarginatum	Tartary	Tetraploid	Emarginatum
Untreated	140	151	214	-------	-------	-------
Limestone	148	224	270	303	-------	-------
Phosphorus	142	161	262	-------	-------	-------
Limestone-phosphorus	165	131	206	284	-------	-------
Phosphorus-potassium	144	207	187	-------	-------	-------
Limestone-phosphorus-potassium	100	137	103	186	-------	-------
Nitrogen-phosphorus-potassium	138	159	172	248	258	245
Limestone - nitrogen - phosphorus-potassium	83	93	138	222	223	229

Production of Rutin

Table 15 includes data on the rutin contents of the buckwheat. As measured by the percentage increase in yields of rutin, the Japanese variety showed a much greater response to the fertilizers than did the Tartary, suggesting that the Tartary buckwheat grown on this soil was a stronger feeder for residual plant food. The most significant data in table 15 are the percentage and acre yields of rutin by the Tartary buckwheat, as compared with those by the Japanese. Both the percentage and acre yields of the Tartary were more than twice those of the Japanese. When grown on soil treated with limestone-nitrogen-phosphorus-potassium, the Tetraploid, Emarginatum, and Tartary varieties produced about the same yields of rutin. Table 16 shows the relative effects of the fertilizer treatments on the production of rutin and the relative yields of rutin by the Japanese and Tartary varieties. Table 17 shows more clearly the superiority of the Tartary, Tetraploid, and Emarginatum varieties over the Japanese in the production of rutin.

Height of Plants

Table 18 shows the average height of the buckwheat grown on each of the plots. The plants on the seven treated plots were higher than those on the untreated plots. In general, the fertilizer treatments produced plants of similar height.

Buckwheat Grown on Lansdale Soil

Production of Dry Matter

Table 19 shows the effects of two rates of nitrogen application and three rates of seeding on yields of dry matter by buckwheat grown on Lansdale soil. Table 20 gives a summary of the yields of dry matter per plant and per acre. There were no significant differences in yields of dry matter due to the rate of application of nitrogen, but the rate of seeding had a tremendous effect on the size of the plants and yields per acre. The individual plants grown in the rows 14 inches apart weighed approximately five times that of the plants in the rows 7 inches apart with plants spaced 1 inch apart in the row. The more thickly planted plots, however, yielded about twice as much dry matter per acre, owing to the greater number of plants per acre.

Table 21 shows the effects of the rates of seeding and application of nitrogen on the yields of leaves and stems. Although the 48-pound-per-acre applications of nitrogen usually increased the yield by each variety, the increase was extremely small and did not justify the additional application.

The Silverhull leaf yields were considerably less than those of the other varieties. Leaf yields of this variety were only 63 percent of the Tartary yields. The results obtained with the Silverhull were similar to those with the Japanese in the other experiments.

Table 18.—*Effects of fertilizers on the height (average) of four varieties of buckwheat grown on Hagerstown soil at State College*

Fertilizer	Japanese	Tartary	Tetraploid	Emarginatum
Plants 29 days old				
	Inches	*Inches*	*Inches*	*Inches*
Untreated	22	8	6	9
Limestone	28	13	7	16
Phosphorus	25	11	6	13
Limestone-phosphorus	24	14	8	17
Phosphorus-potassium	27	15	8	18
Limestone-phosphorus-potassium	20	10	7	15
Nitrogen-phosphorus-potassium	26	12	7	19
Limestone-nitrogen-phosphorus-potassium	25	12	8	16
Plants 36 days old				
Untreated	29	15	14	20
Limestone	31	29	18	28
Phosphorus	30	29	12	22
Limestone-phosphorus	29	28	18	27
Phosphorus-potassium	34	35	19	28
Limestone-phosphorus-potassium	27	21	14	24
Nitrogen-phosphorus-potassium	31	25	18	29
Limestone-nitrogen-phosphorus-potassium	30	26	17	26
Plants 43 days old				
Untreated	29	22	20	31
Limestone	30	41	27	35
Phosphorus	30	36	17	31
Limestone-phosphorus	30	38	26	36
Phosphorus-potassium	32	43	29	40
Limestone-phosphorus-potassium	28	33	25	34
Nitrogen-phosphorus-potassium	32	39	25	39
Limestone-nitrogen-phosphorus-potassium	30	36	25	36

TABLE 19.—*Effects of rates of seeding and application of nitrogen on the production of dry matter and rutin by varieties of buckwheat grown on Lansdale soil*

Rows 7 inches apart; plants spaced 1 inch apart in row

Buckwheat variety	Age of plants (days)	Dry matter content—plots treated with nitrogen at the rate of—		Yield of dry matter per plant—plots treated with nitrogen at the rate of—		Yield of dry matter per acre—plots treated with nitrogen at the rate of—		Rutin content—plots treated with nitrogen at the rate of—		Yield of rutin per plant—plots treated with nitrogen at the rate of—		Yield of rutin per acre—plots treated with nitrogen at the rate of—	
		24 pounds per acre	48 pounds per acre	24 pounds per acre	48 pounds per acre	24 pounds per acre	48 pounds per acre	24 pounds per acre	48 pounds per acre	24 pounds per acre	48 pounds per acre	24 pounds per acre	48 pounds per acre
		Percent	*Percent*	*Grams*	*Grams*	*Pounds*	*Pounds*	*Percent*	*Percent*	*Mg.*	*Mg.*	*Pounds*	*Pounds*
Silverhull	25	13. 1	13. 5	1. 4	1. 1	2, 770	2, 170	4. 01	3. 89	56	43	111	84
	32	11. 4	11. 4	2. 1	2. 2	4, 150	4, 350	4. 01	3. 86	84	85	166	168
	39	16. 0	18. 7	2. 7	2. 6	5, 340	5, 140	3. 54	2. 91	96	76	189	150
	46	19. 4	20. 9	3. 4	3. 2	6, 720	6, 320	2. 58	2. 03	88	65	173	128
	53	23. 4	23. 1	3. 3	3. 0	6, 520	5, 930	1. 94	1. 77	64	53	127	105
Tartary	34	13. 4	13. 2	2. 0	2. 1	3, 950	4, 150	4. 85	4. 42	97	93	192	183
	41	15. 1	16. 6	2. 8	2. 8	5, 530	5, 530	4. 65	4. 31	130	121	257	238
	50	22. 4	20. 1	3. 7	3. 4	7, 310	6, 720	3. 39	3. 41	125	116	248	229
	55	24. 1	22. 9	3. 5	3. 9	6, 920	7, 710	3. 07	2. 96	107	115	212	228
	63	27. 7	28. 5	5. 0	5. 7	9, 880	11, 260	2. 37	2. 38	119	136	234	268
Tetraploid	34	12. 0	14. 0	2. 1	1. 7	4, 150	3, 360	5. 42	5. 11	114	87	225	172
	41	17. 5	17. 4	2. 8	2. 9	5, 530	5, 730	4. 11	4. 34	115	126	227	249
	50	19. 2	14. 6	3. 1	3. 1	6, 130	6, 130	4. 30	5. 17	133	160	264	317
	55	19. 1	18. 4	3. 4	3. 8	6, 720	7, 510	4. 95	4. 03	168	153	333	303
	63	19. 3	22. 3	3. 9	4. 8	7, 710	9, 490	4. 37	3. 40	170	163	337	323
Emarginatum	25	13. 3	15. 1	1. 1	1. 2	2, 170	2, 370	4. 03	3. 31	44	40	88	78
	32	10. 8	11. 8	2. 0	2. 0	3, 950	3, 950	4. 43	3. 82	89	76	175	151
	39	15. 0	12. 6	2. 5	2. 8	4, 940	5, 530	3. 44	3. 57	86	100	170	197
	46	16. 3	14. 2	3. 2	3. 3	6, 320	6, 520	3. 80	3. 34	122	110	240	218
	53	14. 8	16. 8	3. 2	3. 6	6, 320	7, 110	4. 42	2. 85	141	103	279	203
	60	19. 4	20. 2	4. 5	5. 0	8, 890	9, 880	3. 65	3. 12	164	156	325	308
	67	21. 1	20. 2	6. 3	5. 0	12, 450	9, 880	3. 18	3. 24	200	162	396	320

TABLE 19.—*Effects of rates of seeding and application of nitrogen on the production of dry matter and rutin by varieties of buckwheat grown on Lansdale soil*—Continued

Rows 14 inches apart; plants spaced 4 inches apart in row

Buckwheat variety	Age of plants (days)	Dry matter content—plots treated with nitrogen at the rate of—		Yield of dry matter per plant—plots treated with nitrogen at the rate of—		Yield of dry matter per acre—plots treated with nitrogen at the rate of—		Rutin content—plots treated with nitrogen at the rate of—		Yield of rutin per plant—plots treated with nitrogen at the rate of—		Yield of rutin per acre—plots treated with nitrogen at the rate of—	
		24 pounds per acre	48 pounds per acre	24 pounds per acre	48 pounds per acre	24 pounds per acre	48 pounds per acre	24 pounds per acre	48 pounds per acre	24 pounds per acre	48 pounds per acre	24 pounds per acre	48 pounds per acre
		Percent	*Percent*	*Grams*	*Grams*	*Pounds*	*Pounds*	*Percent*	*Percent*	*Mg.*	*Mg.*	*Pounds*	*Pounds*
Silverhull	25	13.9	15.3	2.4	2.8	590	690	4.13	4.14	99	116	25	29
	32	13.2	12.9	4.7	5.7	1,160	1,410	3.42	3.65	161	208	40	51
	39	16.0	14.2	12.4	8.8	3,070	2,170	2.84	3.30	352	290	87	72
	46	15.7	19.4	11.9	18.4	2,960	4,550	2.79	2.28	332	420	83	104
	53	19.0	18.7	16.7	16.7	4,130	4,050	2.34	2.38	391	390	97	96
Tartary	34	12.1	11.9	5.4	6.2	1,330	1,530	4.18	3.93	226	244	56	60
	41	13.8	12.6	11.1	9.1	2,740	2,250	4.49	4.29	498	390	123	97
	50	16.3	14.9	17.9	14.5	4,420	3,580	3.55	3.58	635	519	157	126
	55	19.0	18.9	22.4	24.8	5,530	6,130	3.41	3.01	764	747	189	185
	63	27.0	26.0	24.6	40.7	6,080	10,050	2.40	1.92	590	781	146	193
Tetraploid	34	10.9	10.9	4.5	4.9	1,110	1,210	4.89	4.89	220	240	54	59
	41	12.6	12.4	10.5	11.2	2,590	2,770	4.51	5.04	474	565	117	140
	50	12.1	15.2	13.1	19.8	3,260	4,890	4.64	3.89	608	770	151	190
	55	15.7	19.5	20.6	24.4	5,090	6,030	4.63	3.95	954	964	236	238
	63	19.2	21.4	28.2	28.9	6,970	7,140	4.16	3.38	1,173	977	290	241
Emarginatum	25	17.8	15.9	2.8	3.0	690	740	3.30	3.74	92	112	23	28
	32	11.0	11.7	4.3	6.8	1,060	1,680	3.79	3.78	163	257	40	64
	39	13.0	12.0	10.9	9.6	2,680	2,370	3.16	3.07	344	295	85	73
	46	14.7	11.6	12.3	10.7	3,040	2,640	3.64	3.49	448	373	111	92
	53	19.1	15.3	23.1	21.4	5,710	5,290	2.23	3.52	515	753	127	186
	60	17.1	17.2	21.1	24.1	5,210	5,950	2.64	3.59	557	865	138	214
	67	20.3	21.2	32.7	29.2	8,080	7,210	3.07	2.32	1,004	677	248	167

Rows 14 inches apart; plants spaced 6 inches apart in row

Silverhull	25	15. 3	14. 6	3. 0	2. 8	500	460	4. 56	4. 23	137	118	23	20
	32	12. 2	11. 9	4. 2	6. 9	690	1, 140	4. 22	3. 65	177	252	29	42
	39	15. 2	17. 5	9. 8	19. 9	1, 620	3, 280	3. 51	2. 63	344	523	57	86
	46	16. 3	13. 1	17. 8	19. 6	2, 940	3, 230	2. 73	2. 31	486	453	80	75
	53	19. 6	21. 8	21. 3	31. 0	3, 520	5, 120	1. 60	1. 98	341	614	56	101
Tartary	34	11. 2	10. 3	5. 5	6. 3	910	1, 040	4. 81	4. 64	265	292	44	48
	41	12. 6	12. 3	10. 0	11. 9	1, 650	1, 960	4. 85	4. 24	485	505	80	83
	50	14. 7	13. 7	18. 3	20. 4	3, 020	3, 370	3. 91	3. 64	716	743	118	123
	55	18. 1	17. 1	26. 9	32. 7	4, 440	5, 400	3. 27	3. 71	880	1, 213	145	200
	63	12. 8	20. 8	33. 7	34. 2	5, 560	5, 640	3. 02	3. 24	1, 018	1, 108	168	183
Tetraploid	34	11. 5	11. 3	4. 4	5. 4	730	890	4. 12	4. 21	181	227	30	38
	41	12. 0	12. 3	13. 0	12. 7	2, 150	2, 100	5. 11	4. 89	664	621	110	103
	50	11. 3	12. 8	16. 8	20. 8	2, 770	3, 430	4. 90	4. 61	823	959	136	158
	55	14. 5	16. 0	22. 5	24. 8	3, 710	4, 090	4. 74	4. 22	1, 067	1, 047	176	173
	63	17. 7	16. 5	27. 8	25. 7	4, 590	4, 240	4. 11	4. 75	1, 143	1, 221	189	201
Emarginatum	25	16. 3	15. 1	2. 4	3. 1	400	510	4. 28	3. 93	103	122	17	20
	32	11. 9	10. 6	6. 5	7. 8	1, 070	1, 290	3. 73	3. 60	243	281	40	46
	39	14. 4	12. 2	14. 4	12. 4	2, 380	2, 050	3. 16	3. 02	344	375	75	62
	46	13. 5	12. 3	23. 4	18. 4	3, 860	3, 040	3. 37	2. 82	789	519	130	86
	53	16. 5	14. 2	21. 6	24. 0	3, 560	3, 960	3. 02	3. 56	652	854	108	141
	60	20. 5	19. 6	34. 9	42. 5	5, 760	7, 010	2. 66	2. 68	928	1, 139	153	188
	67	17. 9	21. 6	32. 9	50. 8	6, 470	8, 380	3. 06	1. 97	1, 200	1, 001	198	165

TABLE 20.—*Summary* [1] *of effects of rates of seeding and application of nitrogen on the production of dry matter and rutin by four varieties of buckwheat grown on Lansdale soil*

Nitrogen applied per acre (pounds)	Dry matter per plant				Dry matter per acre				Rutin content				Yields of rutin per acre			
	Silver-hull	Tar-tary	Tetra-ploid	Emar-gina-tum	Silver-hull	Tar-tary	Tetra-ploid	Emar-gina-tum	Silver-hull	Tar-tary	Tetra-ploid	Emar-gina-tum	Silver-hull	Tar-tary	Tetra-ploid	Emar-gina-tum
Rows 7 inches apart; plants spaced 1 inch apart in row																
	Grams	*Grams*	*Grams*	*Grams*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Percent*	*Percent*	*Percent*	*Percent*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
24	2. 6	3. 4	3. 1	3. 3	5, 100	6, 720	6, 050	6, 430	3. 22	3. 67	4. 63	3. 85	153	229	277	239
48	2. 4	3. 6	3. 3	3. 3	4, 780	7, 070	6, 440	6, 460	2. 89	3. 50	4. 41	3. 32	127	229	273	211
Average	2. 5	3. 5	3. 2	3. 3	4, 940	6, 900	6, 250	6, 450	3. 06	3. 59	4. 52	3. 59	140	229	275	225
Rows 14 inches apart; plants spaced 4 inches apart in row																
24	9. 7	16. 3	15. 4	15. 3	2, 380	4, 020	3, 800	3, 780	3. 10	3. 61	4. 57	3. 12	66	134	169	110
48	10. 4	19. 1	17. 8	15. 0	2, 570	4, 710	4, 410	3, 700	3. 15	3. 35	4. 23	3. 36	70	132	174	118
Average	10. 1	17. 7	16. 6	15. 2	2, 480	4, 370	4, 110	3, 740	3. 13	3. 48	4. 40	3. 24	68	133	172	114
Rows 14 inches apart; plants spaced 6 inches apart in row																
24	11. 2	18. 9	16. 9	19. 4	1, 850	3, 120	2, 790	3, 360	3. 32	3. 97	4. 60	3. 33	49	111	128	103
48	16. 0	21. 1	17. 9	22. 7	2, 650	3, 480	2, 950	3, 750	2. 96	3. 89	4. 54	3. 08	65	127	135	101
Average	13. 6	20. 0	17. 4	21. 1	2, 250	3, 300	2, 870	3, 550	3. 14	3. 93	4. 57	3. 21	57	119	132	102

[1] Average of all samples.

TABLE 21.—*Effects of rates of seeding and application of nitrogen on yields of leaves and stems by four varieties of buckwheat grown on Lansdale soil*

Age of plants (days)	Nitrogen application per acre	Leaves per acre				Stems per acre				Total dry matter per acre			
		Silver-hull	Tartary	Tetra-ploid	Emargi-natum	Silver-hull	Tartary	Tetra-ploid	Emargi-natum	Silver-hull	Tartary	Tetra-ploid	Emargi-natum
Rows 7 inches apart; plants spaced 1 inch apart in row													
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
40	24	1, 190	1, 860	2, 420	1, 670	4, 150	3, 670	3, 110	3, 270	5, 340	5, 530	5, 530	4, 940
	48	1, 240	1, 970	2, 650	2, 190	3, 900	3, 560	3, 080	3, 340	5, 140	5, 530	5, 730	5, 530
54	24	1, 030	1, 720	2, 600	1, 810	5, 490	5, 200	4, 120	4, 510	6, 520	6, 920	6, 720	6, 320
	48	1, 180	1, 770	3, 010	2, 250	4, 750	5, 940	4, 500	4, 860	5, 930	7, 710	7, 510	7, 110
Rows 14 inches apart; plants spaced 4 inches apart in row													
40	24	980	1, 190	1, 470	1, 210	2, 090	1, 550	1, 120	1, 470	3, 070	2, 740	2, 590	2, 680
	48	760	1, 020	1, 530	1, 040	1, 410	1, 230	1, 240	1, 330	2, 170	2, 250	2, 770	2, 370
54	24	830	1, 710	1, 910	1, 860	3, 300	3, 820	3, 180	3, 850	4, 130	5, 530	5, 090	5, 710
	48	840	2, 010	2, 580	1, 750	3, 210	4, 120	3, 450	3, 540	4, 050	6, 130	6, 030	5, 290
Rows 14 inches apart; plants spaced 6 inches apart in row													
40	24	420	770	1, 160	1, 160	1, 200	880	990	1, 220	1, 620	1, 650	2, 150	2, 380
	48	1, 200	970	1, 220	850	2, 080	990	880	1, 200	3, 280	1, 960	2, 100	2, 050
54	24	680	1, 420	1, 780	1, 560	2, 840	3, 020	1, 930	2, 000	3, 520	4, 440	3, 710	3, 560
	48	1, 070	1, 880	1, 960	1, 460	4, 050	3, 520	2, 130	2, 500	5, 120	5, 400	4, 090	3, 960

Production of Rutin

Table 19 includes detailed results on the effects of the rates of seeding and the application of nitrogen and also the age of the plants on the yield of rutin. The rutin content was not affected by the rate of seeding, but was greatly affected by the age of the plants. The rutin content of the Silverhull variety decreased rapidly with maturity; it ranged from more than 4 percent in young plants to less than 2 percent in older plants. In this respect the Silverhull was like the Japanese. The Tartary showed more variation in rutin content with age; Emarginatum showed the least variation. The effects of the two rates of nitrogen application on the rutin content were variable, probably owing to errors in sampling and analyses.

The results on the rutin content of individual plants paralleled the results on dry matter. Thus, the average yield of rutin per plant grown in the rows 7 inches apart was 110 milligrams, as compared with 490 and 618 milligrams for the plants grown 4 and 6 inches apart, respectively, in the rows 14 inches apart. The average yields per acre in the same order were 217, 122, and 103 pounds (table 22).

This lower yield per acre by plants grown in rows 14 inches apart was due to the fewer plants per acre. The data on rutin production in table 22 clearly indicate the superiority of the Tartary, Tetraploid, and Emarginatum varieties over the Silverhull.

Height of Plants

Table 23 shows that neither the rate of seeding nor the rate of nitrogen application had any appreciable effect on the height of the buckwheat.

Resistance to Storm Damage

On August 10, 54 days from the date of emergence of the plants, the proportion of plants that had lodged during a severe rain and wind storm was noted. The data in table 24 show the extent of lodging. The percentage of lodging depends on the maturity of the plants. The Tartary and Tetraploid varieties mature about 2 weeks later than the Silverhull. The 48-pound-per-acre application of nitrogen significantly increased the degree of lodging of all varieties. There is little evidence that the rate of seeding had any appreciable effect on lodging. The relatively low degree of lodging of the Emarginatum was undoubtedly due to poor yield of seed, which is characteristic of this variety as compared with others, especially the Japanese and Silverhull. Figure 6 shows the extensive damage suffered by the Silverhull even when 39 days old; the Tartary was undamaged.

TABLE 22.—*Average effects of rate of seeding on yields of leaves and rutin by four varieties of buckwheat grown on Lansdale soil*

Rate of seeding		Leaves per acre [1]				Rutin per acre [2]			
Inches between rows	Inches between plants in row	Silverhull	Tartary	Tetraploid	Emarginatum	Silverhull	Tartary	Tetraploid	Emarginatum
		Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
7	1	1, 160	1, 830	2, 670	1, 980	140	229	275	225
14	4	850	1, 480	1, 870	1, 460	68	133	172	114
14	6	840	1, 260	1, 530	1, 260	57	119	131	102

[1] Average dry weight of 40- and 54-day-old plants.
[2] Average of all samples.

TABLE 23.—*Effects of rates of seeding and application of nitrogen on the height of four varieties of buckwheat grown on Lansdale soil*

Rate of seeding: Inches between rows	Rate of seeding: Inches between plants in row	Per acre rate of nitrogen application	Silverhull	Tartary	Tetraploid	Emarginatum
Plants 21 days old						
		Pounds	*Inches*	*Inches*	*Inches*	*Inches*
7	1	24	20	10	8	14
		48	18	10	6	13
14	4	24	16	9	6	11
		48	14	6	5	10
14	6	24	13	6	5	9
		48	13	6	5	9
Plants 40 days old						
7	1	24	44	43	34	39
		48	41	40	34	39
14	4	24	40	36	28	34
		48	38	33	26	34
14	6	24	38	30	22	31
		48	35	32	24	33
Plants 54 days old						
7	1	24	46	46	43	51
		48	44	47	41	50
14	4	24	44	46	39	49
		48	44	46	37	48
14	6	24	41	42	39	47
		48	45	44	34	48

TABLE 24.—*Effects of rates of seeding and application of nitrogen on lodging of four varieties of buckwheat. Plants were 54 days old.*

Buckwheat variety	Plants lodged on plots: Treated with nitrogen at the rate of—24 pounds per acre	Plants lodged on plots: Treated with nitrogen at the rate of—48 pounds per acre	Plants lodged on plots: Rows 7 inches apart	Plants lodged on plots: Rows 14 inches apart
	Percent [1]	*Percent* [1]	*Percent* [2]	*Percent* [2]
Silverhull	48	60	54	55
Tartary	14	28	32	16
Emarginatum	1	18	1	14
Tetraploid	0	6	1	5

[1] Average of three rates of seeding.
[2] Average of two rates of nitrogen application.

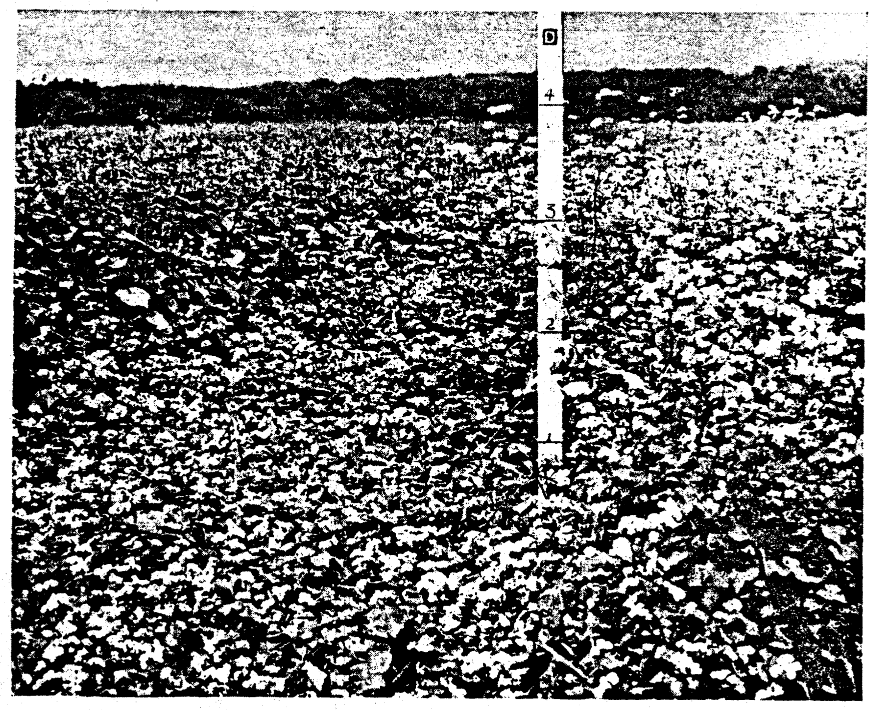


FIGURE 6.—Buckwheat 39 days old. Silverhull (foreground) is severely damaged by lodging; Tartary (background) is undamaged.

DISCUSSION

Effects of Age and Planting Date

Figure 7 shows the effects of age of plant and date of planting on the rutin content and the yields of rutin and dry matter by Tartary and Japanese buckwheat. The peak of rutin content was reached about 25 to 35 days after emergence of the plants, which is the time of blooming, depending on the species. The Tartary buckwheat was 45 to 80 percent richer in rutin than the Japanese. The rutin content of both species decreased after seeds had formed, although the decrease was slower for the Tartary. The Tartary variety was slower to flower and slower in setting a full crop of seed. It did not mature so rapidly but grew continuously, maintaining a considerable portion of the plant as young immature tissue.

Buckwheat is ordinarily planted for grain production in late June or early July. A study of buckwheat planted on three different dates (fig. 7) showed that the early plantings had the highest percentage of rutin and that the rutin content was progressively less in the later plantings. The yield of dry matter, on the other hand, increased significantly in later plantings, with a comparative increase in the yield of rutin per acre. Similar results (fig. 8) were obtained in 1948 with four plantings of Tartary on Lansdale silt loam.

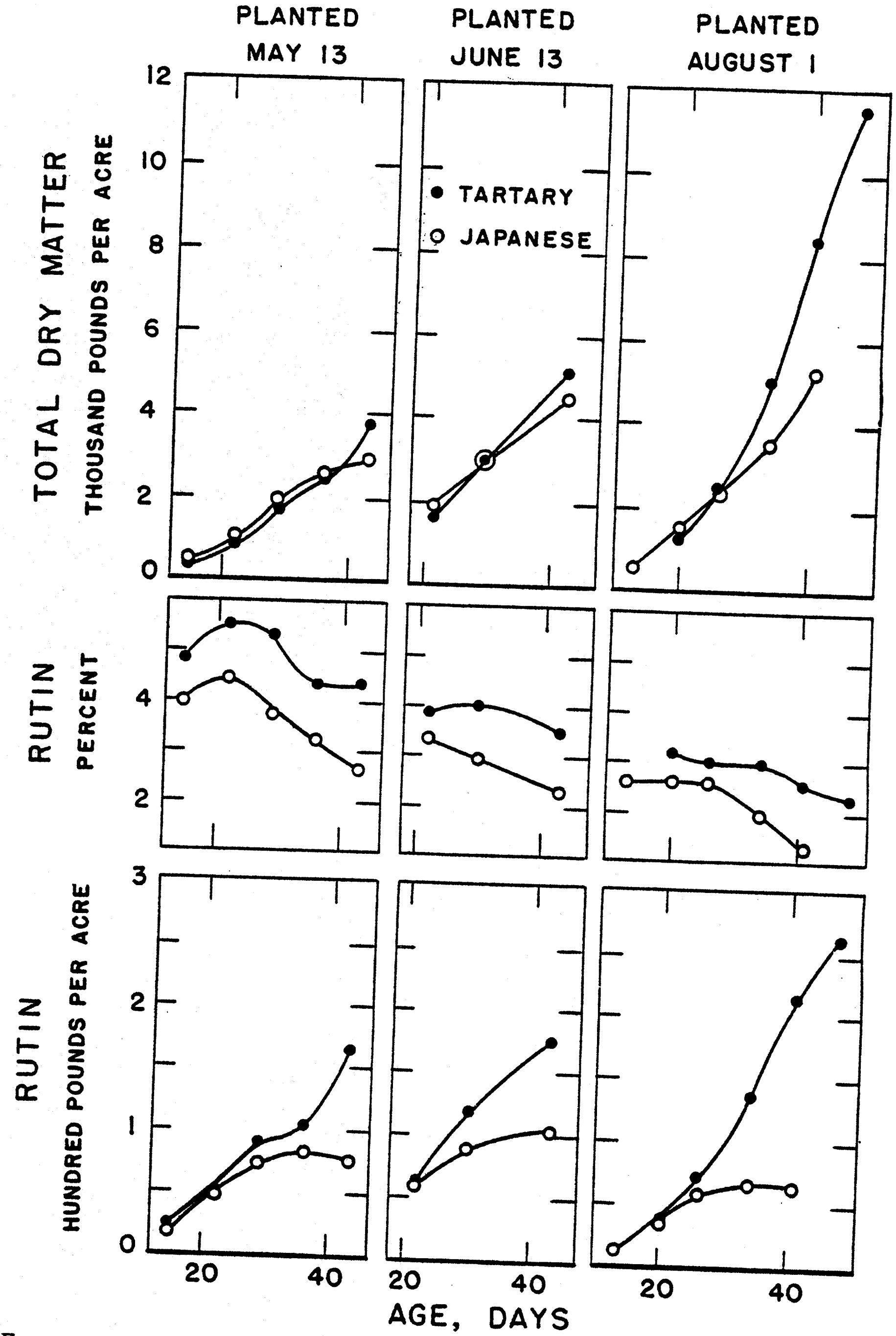


FIGURE 7.—Effect of age of plant on the production of rutin and dry matter by two varieties of buckwheat planted at three different times during the growing season.

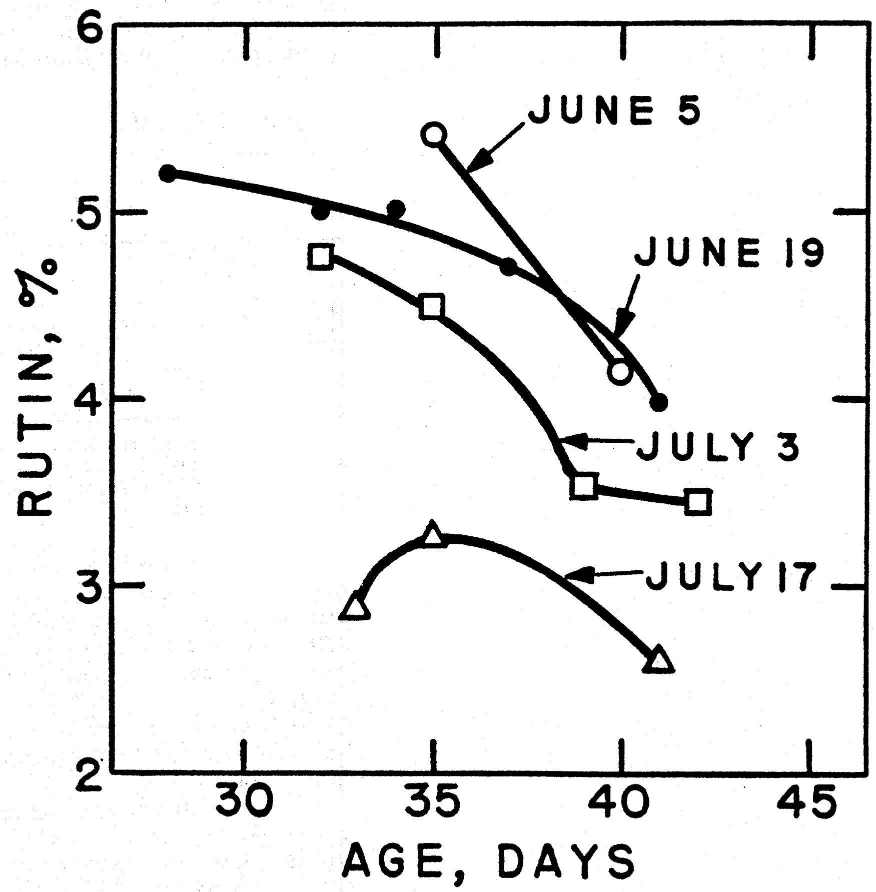


FIGURE 8.—Effect of date of planting on the rutin content of Tartary buckwheat grown on Lansdale silt loam.

It appears that in order to obtain buckwheat plants rich enough in rutin (*12, 14*) to be capable of competing with richer imported sources (*Sophora japonica* flower buds (*2*) and Eucalyptus leaves (*10*)), it may be necessary to restrict planting to the early part of the season. Furthermore, buckwheat will have to be harvested at the peak of its rutin content. The best time will vary somewhat with the season but will be about 4 to 6 weeks after planting.

Effect of Variety

Table 25 shows the yields of leaves and rutin produced by the five varieties of buckwheat studied in these experiments. The three varieties of indeterminate type of growth—Tartary, Tetraploid, and Emarginatum—produced greater yields of both leaves and rutin than the Japanese and Silverhull, which have a determinate type of growth. The first three varieties appear to be equally suited for rutin production, but only the Tartary seed is available in commercial quantities. The Tartary variety yielded 10 percent more leaf and 65 percent more rutin than the Japanese, and 16 and 82 percent, respectively, more than the Silverhull.

TABLE 25.—*Yields of leaves and rutin by different varieties of buckwheat*

Buckwheat variety	Leaves per acre	Rutin per acre
	Pounds	*Pounds*
Japanese [1]	1, 000	97
Silverhull [2]	950	88
Tartary [1]	1, 100	160
Tetraploid [1]	1, 480	164
Emarginatum [1]	1, 320	144

[1] Average of all results on Dekalb, Volusia, and Hagerstown (State College) soils treated with limestone-nitrogen-phosphorus-potassium.
[2] Average of results with three rates of seeding and two rates of nitrogen application on Lansdale soil.

Since these studies were made, several reports have appeared in the literature on the rutin content of different varieties of buckwheat grown in other countries. Paris (*17*) made a study of the rutin contents of two varieties each of *Fagopyrum tataricum* and *F. esculentum* grown in several localities of France and collected in June, July, September, and October. The *F. tataricum* contained more rutin than the *F. esculentum*, which agrees with the results reported here; however, the maximum value of 2.37 percent was smaller than that reported here.

Ibanez, Guiser, and Szabo (*7*), who studied the rutin content of buckwheat grown in Chile, reported a yield of 4.7 percent from fresh whole plant of *Fagopyrum esculentum* harvested in the blooming stage. Opavsky (*16*) reported only 1 percent of rutin in the leaves of *F. esculentum* grown in Poland, and collected in the last stages of bloom. However, he ground the leaves before extraction—a treatment that destroys considerable rutin. Koletskii and Efros (*8*) found from 2.1 to 2.57 percent of rutin in the leaves and flowers and 0.2 percent in the stems of buckwheat grown in Russia.

From Canada, McGregor and McKillican (*11*) reported the results of a 4-year (1947–1950) study of buckwheat grown on 2 types of soil, with 24 varieties and strains including both *F. tataricum* and *F. esculentum*. Each year the buckwheat was planted about the middle of June and harvested when blossoming began, which was usually 35 to 40 days after planting. Unlike the results reported here, their results showed no significant differences in the percentage of rutin between the different strains tested. The explanation for this apparent anomaly is that the 20 strains and varieties of *F. esculentum* tested by McGregor and McKillican included several that were exceptionally rich in rutin, having an equal or greater rutin content than the *F. tataricum* strains. Their results indicate the possibility of developing a high-rutin buckwheat, either by selection or by breeding.

Effect of Rate of Seeding

In the experiment on Lansdale soil, buckwheat seeded in accordance with the common practice for grain production—rows 7 inches apart and plants spaced approximately 1 inch apart in the row—gave an average of 25 to 37 percent higher yields of leaves and of rutin than plants grown in rows 14 inches apart. In addition, the yield of rutin in this experiment was higher than that produced in the other four experiments, in which the buckwheat was planted in rows 12 inches apart. If the highest yield of rutin by Tartary buckwheat in the 7-inch rows is taken as 100, the other plantings had the following values: Rows 12 inches apart, 72; rows 14 inches apart, 74. Expressed as maximum yields per acre of rutin, these values are rows 7 inches apart, 268 pounds; rows 12 inches apart, 194 pounds; and rows 14 inches apart, 198 pounds.

Another important advantage of thicker planting is that it prevents the growth of weeds. Where the rows were 14 inches apart, it was necessary to cultivate between the rows several times during the experiment, but this was not necessary where the rows were 7 inches apart. Buckwheat planted with a grain drill, in accordance with usual farm practice, has the greatest value of any grain crop for the elimination of weeds. Within a few weeks, the entire area is covered with a heavy growth of leaves, which inhibits weed growth.

Effects of Fertilizers

The data in table 26, which are average results on the Dekalb, Volusia, and Hagerstown (State College) soils, show that both limestone-phosphorus and limestone-nitrogen-phosphorus-potassium increased yields of buckwheat dry matter more than limestone alone. The plots treated with limestone-phosphorus-potassium, however, showed little, if any, gain in yields; in fact, the Emarginatum variety produced 540 pounds (14 percent) less dry matter than when limestone was used alone. The most significant results in table 26 are the effects of limestone-nitrogen-phosphorus-potassium on yields of leaves and stems—an increase (average of all varieties) of 320 pounds (35 percent) of leaves and 650 pounds (27 percent) of stems over that produced by limestone-phosphorus-potassium.

The data in table 27 emphasize the importance of nitrogen in the production of rutin by buckwheat grown on the Dekalb soil and the Hagerstown soil at State College. The Hagerstown soil at Lancaster contained high residual nutrients from previous fertilizations. As already explained, the low response to applied nitrogen on the Volusia soil was due to the fact that a clover sod had been plowed under the preceding fall, thus supplying most of the nitrogen required. The limestone-phosphorus and limestone-phosphorus-potassium gave higher yields of rutin than did limestone alone.

TABLE 26.—*Effects of fertilizers on yields of leaves and stems by four varieties of buckwheat grown on Dekalb, Volusia, and Hagerstown [1] soils*

Fertilizer	Leaves per acre [2]				Stems per acre [2]			
	Japanese	Tartary	Tetraploid	Emarginatum	Japanese	Tartary	Tetraploid	Emarginatum
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Limestone	620	720	1, 160	1, 130	2, 720	2, 120	1, 720	2, 810
Limestone-phosphorus	700	930	1, 290	1, 120	3, 190	2, 520	2, 140	2, 800
Limestone-phosphorus-potassium	670	810	1, 180	960	2, 770	2, 420	1, 910	2, 440
Limestone-nitrogen-phosphorus-potassium	1, 000	1, 100	1, 480	1, 320	3, 640	3, 040	2, 640	2, 920

[1] At State College.
[2] Average of all samples.

TABLE 27.—*Relative effects of fertilizers on the yields of rutin by four varieties of buckwheat grown on three types of soil. (Limestone=100)*

Fertilizer	By Japanese grown on—				By Tartary grown on—			
	Dekalb soil	Volusia soil	Hagerstown soil at State College	Hagerstown soil at Lancaster [1]	Dekalb soil	Volusia soil	Hagerstown soil at State College	Hagerstown soil at Lancaster [1]
Limestone-phosphorus	113	118	141	127	116	118	132	144
Limestone-phosphorus-potassium	102	110	175	131	123	117	108	143
Limestone-nitrogen-phosphorus-potassium	142	103	204	138	178	114	148	142

[1] At Lancaster (Untreated=100).

Effect of Soil Type

Table 28 shows the effect of soil type on the production of rutin by four varieties of buckwheat. The Japanese, Tartary, and Tetraploid varieties produced their highest yields when grown on Volusia soil. The next highest yields were produced on Lansdale soil, followed closely by those on the Hagerstown soil at State College. Emarginatum gave its highest yields on this Hagerstown soil, and the Tartary, Tetraploid, and Emarginatum showed the greatest increase over the Japanese on this soil.

TABLE 28.—*Effect of soil type on the production of rutin by four varieties of buckwheat*

Soil type	Rutin—per acre [1]				Increase over production of rutin by Japanese		
	Japanese	Tartary	Tetraploid	Emarginatum	Tartary	Tetraploid	Emarginatum
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Percent*	*Percent*	*Percent*
Dekalb	97	140	136	124	44. 3	40. 2	27. 8
Volusia	121	180	193	146	48. 8	59. 5	20. 7
Hagerstown:							
At State College	73	162	163	167	121. 9	123. 3	128. 8
At Lancaster [2]	68	121			77. 9		
Lansdale [3]	[4] 88	160	193	147	[5] 81. 8	[5] 119. 3	[5] 67. 0

[1] Average of all samples from plots treated with limestone-nitrogen-phosphorus-potassium or nitrogen-phosphorus-potassium.
[2] Average of three plantings.
[3] Average results with three rates of seeding and two rates of nitrogen application.
[4] Silverhull.
[5] Increase over production by Silverhull.

Effect of Manner of Harvesting

Yields of buckwheat dry matter in these experiments are based on the weights of plants cut at ground level. In three of the experiments a portion was cut from the base of the stems and weighed separately. In this way it was possible to determine the percentage of the stems that would be left in the field as stubble if the buckwheat was harvested at this height. Later the dry weight of this portion was added to the weight of the remaining stem dry matter. Table 29 gives the weights of the stems of the four varieties cut 4 inches above the ground. These data show that an average of 7.7 to 13.9 percent of the total dry matter would be in the stubble. The Tartary, Tetraploid, and Emarginatum varieties showed greater weights of stubble than the Japanese. Because the stubble contains little rutin, discarding this quantity of dry matter would increase the percentage of rutin in the harvested plant by approximately one-tenth. Harvesting at a higher level would give an even greater increase. As the

TABLE 29.—*Effect of harvesting four varieties of buckwheat 4 inches above the ground on the quantity of dry matter left as stubble*

Soil type	Dry matter per acre left as stubble							
	Japanese		Tartary		Tetraploid		Emarginatum	
	Pounds	*Percent* [1]	*Pounds*	*Percent* [1]	*Pounds*	*Percent* [1]	*Pounds*	*Percent* [1]
Dekalb	290	7.1	530	11.6	560	15.5	440	10.7
Volusia	360	6.9	540	10.2	570	15.8	480	11.9
Hagerstown at State College	270	9.0	430	15.8	560	10.5	490	14.2
Average	307	7.7	500	12.5	563	13.9	470	12.3

[1] Based on dry matter when buckwheat was harvested at ground level.

level is raised, however, there will be increasing loss of leaves from the lower lateral branches.

The Tartary and Tetraploid varieties produced a relatively greater number of low lateral branches than either the Japanese or Silverhull (fig. 9), and if cut at a height above 4 inches, especially in the thinner planting, the stubble from these varieties would include an appreciable percentage of the basal leaves. Thick plantings, which have

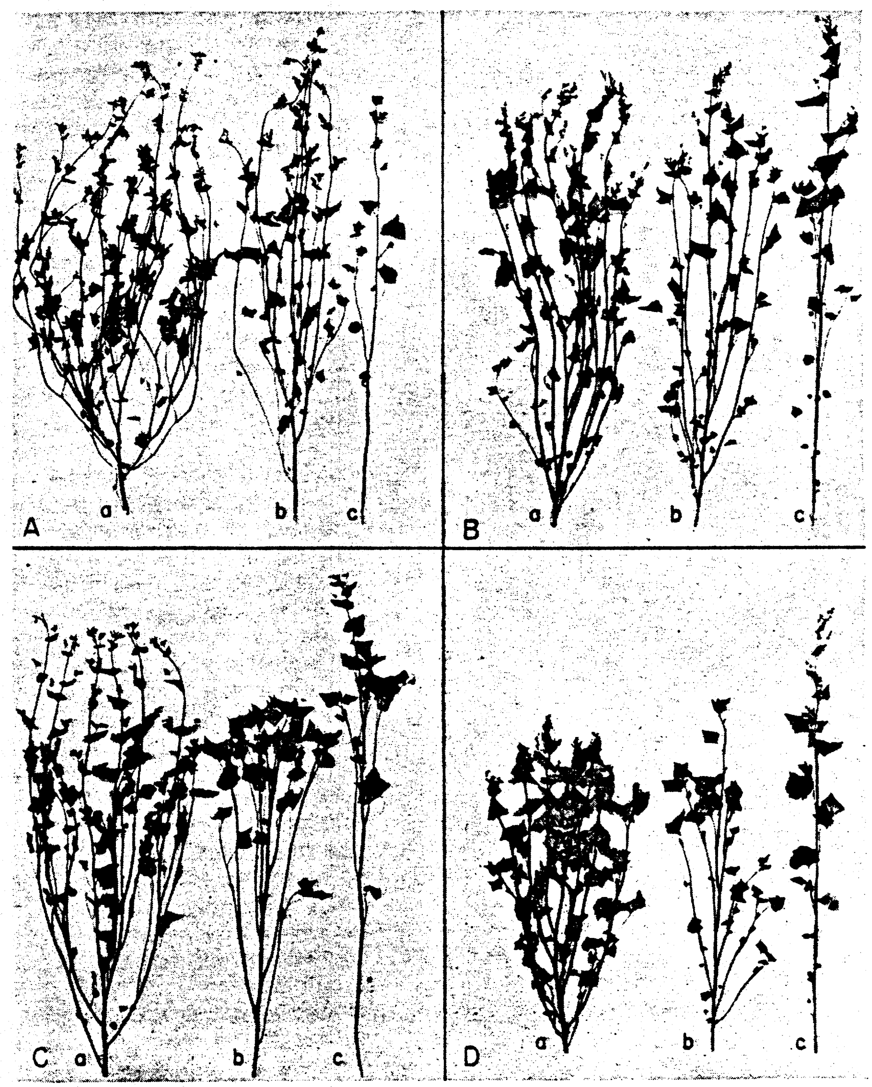


FIGURE 9.—Forty-one-day-old buckwheat grown at different spacings: *A*, Silverhull; *B*, Tartary; *C*, Emarginatum; *D*, Tetraploid; *a*, grown in rows 14 inches apart and spaced 6 inches apart in the row; *b*, grown in rows 14 inches apart and spaced 4 inches apart in the row; *c*, grown in rows 7 inches apart and spaced 1 inch apart in the row.

few basal leaves, can be harvested as much as 12 inches above the ground without appreciable loss of leaves or rutin.

SUMMARY AND RECOMMENDATIONS

During 1946, 1947, and 1948, to determine the effects of age of plants, planting date, fertilizers, rate of seeding, and manner of harvesting on the production of rutin by buckwheat, five varieties—Japanese, Silverhull, Tartary, Tetraploid, and Emarginatum—were grown in central and eastern Pennsylvania on Hagerstown, Dekalb, Volusia, and Lansdale silt loams.

Young plants of all varieties contained a higher percentage of rutin and a higher proportion of leaves to stems than mature plants. The rutin content decreased rapidly with the onset of formation of seed. For rutin production, buckwheat should be harvested at the peak of its rutin content, which for Tartary buckwheat (under normal soil and climatic conditions) is from 4 to 6 weeks from the date of planting, when plants are in bloom.

Buckwheat planted early in the season (May and June) had a higher rutin content than that planted later in the year.

The Tartary, Tetraploid, and Emarginatum varieties had a higher percentage of rutin, did not lose the rutin so rapidly with maturity, and produced higher yields of rutin and leaves per acre than the Japanese and Silverhull. Of the buckwheat varieties for which seed is now available in commercial quantities, Tartary has proved to be the most valuable source of rutin.

Tartary buckwheat produced its highest yields of rutin when seeded in rows 7 inches apart at the rate of 2 to 3 pecks per acre. This rate supplied approximately 1 seed to each inch of row. When planted in this manner, the buckwheat produced a minimum of lateral branches, and could be harvested 6 inches or more above the ground without loss of leaves.

Buckwheat for rutin production should be planted on fertile soil. Soils that have been previously supplied with liberal applications of phosphoric acid and potash need only the additional application of nitrogen, preferably as sulfate of ammonia at the rate of 150 pounds per acre, which will supply approximately 30 pounds of nitrogen. Soils that have not been liberally supplied with mineral plant food should receive an application of a complete fertilizer such as 5-10-5 formula at the rate of 300 pounds per acre if drilled in the row, or 500 pounds per acre if broadcast over the seedbed and harrowed into the soil before seeding. The latter application will supply 25 pounds of nitrogen, 50 pounds of phosphoric acid, and 25 pounds of potash.

In preparing the seedbed for buckwheat, the soil should be plowed several weeks in advance of seeding and harrowed frequently. Before the buckwheat is planted, the seedbed should be cultipacked to assure a compact soil. This last step before seeding is of vital importance. Buckwheat has an extremely limited and shallow root system, which subjects the plants to possible severe drought injury and varied degrees of lodging. The final compaction not only reduces these hazards but also brings the roots into more intimate contact with the soil, thus increasing the rate of absorption of plant food.

LITERATURE CITED

(1) COUCH, J. F., NAGHSKI, J., AND KREWSON, C. F.
1946. BUCKWHEAT AS A SOURCE OF RUTIN. Science 103: 197–198.

(2) ——— NAGHSKI, J., AND KREWSON, C. F.
1952. RUTIN CONTENT OF SOPHORA JAPONICA L. Amer. Chem. Soc. Jour. 74: 424–425.

(3) ——— NAGHSKI, J., WHITE, J. W., and others.
1949. TARTARY BUCKWHEAT AS A SOURCE OF RUTIN. U. S. Dept. Agr., Bur. Agr. and Indus. Chem. AIC–222. 2 pp. (Processed.)

(4) ESKEW, R. K., PHILLIPS, G. W. M., GRIFFIN, E. L. and others.
1948. PRODUCTION OF RUTIN FROM BUCKWHEAT LEAF MEAL. U. S. Dept. Agr., Bur. Agr. and Indus. Chem. AIC–114, rev. 1. 21 pp., illus. (Processed.)

(5) GRIFFITH, J. Q., JR., KREWSON, C. F., AND NAGHSKI, J.
1955. RUTIN AND RELATED FLAVONOIDS. 290 pp., illus. Mack Publishing Company, Easton, Pa.

(6) HUNT. THOMAS F.
1910. CEREALS OF AMERICA. 421 pp., illus. New York, N. Y.

(7) IBANEZ, J., GUISER, R., AND SZABO, E.
1949. LA RUTINA PRODUCIDA EN CHILE. Bol. de la Soc. Biol. [Chile] 7. 19–20.

(8) KOLETSKII, A. M., AND EFROS, R. S.
1952. [ISOLATION OF RUTIN FROM BUCKWHEAT GRASS.] Aptechnoe Delo 1, 38–42. (Abstract in Chem. Abs. 46: 5265. 1952.)

(9) KREWSON, C. F., AND COUCH, J. F.
1950. PRODUCTION OF RUTIN FROM BUCKWHEAT. Amer. Pharm. Assoc. Jour., Sci. Ed., 39, 163–169, illus.

(10) ——— FENSKE, C. S., JR., COUCH, J. F., AND NAGHSKI, J.
1953. RUTIN IN EUCALYPTUS SPECIES. Amer. Jour. Pharm. 125: 117–121.

(11) McGREGOR, W. G., AND McKILLICAN, M. E.
1952. RUTIN CONTENT OF VARIETIES OF BUCKWHEAT. Sci. Agr. 32: 48–51.

(12) NAGHSKI, J., BRICE, B. A., AND KREWSON, C. F.
1952. PRODUCTION OF BUCKWHEAT LEAF MEALS WITH HIGH RUTIN CONTENT. Amer. Jour. Pharm. 124, 297–306, illus.

(13) ——— FENSKE, C. S., JR., KREWSON, C. F., AND COUCH, J. F.
1949. DETERMINATION OF RUTIN IN PLANT MATERIALS. U. S. Dept. Agr., Bur. Agr. and Indus. Chem. AIC–236, 5 pp. (Processed.)

(14) ——— KREWSON, C. F., PORTER, W. L., AND COUCH, J. F.
1950. FACTORS AFFECTING THE RUTIN CONTENTS OF DRIED BUCKWHEAT LEAF MEALS. Amer. Pharm. Assoc. Jour., Sci. Ed., 39: 696–698.

(15) NOLL, C. F., AND IRWIN, C. J.
1942. FIELD TESTS OF PHOSPHATE FERTILIZERS. Pa. Agr. Expt. Sta. Bul. 423, 14 pp.

(16) OPAVSKY, J.
1949. [THE CHEMISTRY AND ISOLATION OF RUTIN.] Casopis Ceského Lékárnictva 62, 84–86. (Abstract in Chem. Abs. 46: 4179. 1952.)

(17) PARIS, R.
1949. LE RUTOSIDE (RUTIN), SA PRÉPARATION À PARTIR DE DIVERSES ESPÈCES ET VARIÉTÉS DE SARRASIN CULTIVÉES EN FRANCE. Ann. Pharm. Franc. 7: 21–26.

(18) PHILLIPS, G. W. M., ACETO, N., ESKEW, R. K., AND HURLEY, R.
1950. PRODUCTION OF BUCKWHEAT LEAF MEAL IN ROTARY ALFALFA DRIERS. U. S. Dept. Agr., Bur. Agr. and Indus. Chem. AIC–264, 9 pp., illus. (Processed.)

(19) QUISENBERRY, K. S., AND TAYLOR, J. W.
1939. GROWING BUCKWHEAT. U. S. Dept. Agr. Farmers' Bul. 1835, 17 pp., illus.

(20) SANDO, W. J.
1939. A COLCHICINE-INDUCED TETRAPLOID IN BUCKWHEAT. Jour. Hered. 30: 271–272.

(21) TRUOG, E.
1930. THE DETERMINATION OF READILY AVAILABLE PHOSPHORUS OF SOILS. Amer. Soc. Agron. Jour. 22: 875–882.

(22) VOLK, N. J., AND TRUOG, E.
1934. A RAPID CHEMICAL METHOD FOR DETERMINING THE READILY AVAILABLE POTASH IN SOILS. Amer. Soc. Agron. Jour. 26: 537–546.

(23) WHITE, J. W., HOLBEN, F. J., AND RICHER, A. C.
1941. EXPERIMENTS WITH BUCKWHEAT. Pa. Agr. Expt. Sta. Bul. 403, 62, pp. illus.